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UNDERWATER FACILITIES INSPECTIONS AND ASSESSMENTS AT
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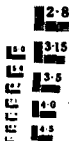
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**UNDERWATER FACILITIES
INSPECTIONS
AND
ASSESSMENTS
AT

NAVAL WEAPONS STATION

CHARLESTON, SC**

FPO-1-81 (7)

MAY 1981

PERFORMED FOR:

**OCEAN ENGINEERING AND CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D.C. 20374**

UNDER:

**CONTRACT N62477-80-C-0102
TASK 5**

BY:

**CHILDS ENGINEERING CORPORATION
MEDFIELD, MASSACHUSETTS 02052**

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The objective of the underwater facility assessments conducted at the U.S.
Naval Weapons Station in Charleston, South Carolina is to provide a
generalized structural condition report of the designated facilities within
the activity. These facilities are Wharf ALPHA, Pier BRAVO and Pier (Con't)

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CHARLIE. Each facility was inspected by a team of engineer/divers using a combination of visual/tactile and ultrasonic techniques. Critical elements were photo-documented.

Wharf ALPHA and Pier CHARLIE appear to be in excellent condition, except for some localized structural damage or environmental deterioration. Wharf ALPHA has some cosmetic spalling on several piles. It is recommended that these areas be patched with an epoxy grout to insure adequate protection of the prestressed reinforcing steel. In Pier CHARLIE, one pile has suffered damage due to impact. It is recommended that the pile also be repaired. Loadings in the vicinity of this pile should be limited to dead load only, until repairs are performed.

Pier BRAVO has seen more deterioration than either Wharf ALPHA or Pier CHARLIE. The concrete encasements are in poor shape and, in some areas, are not protecting the steel H-piles from salt water corrosion. However, steel thickness measurements indicate that the pile foundation is adequate to handle the imposed loads. A reinspection of Pier BRAVO should be conducted in three years to document any further deterioration. This report should be used as a baseline for this future inspection.

FOREWORD

The scope of the inspection at the Naval Weapons Station in Charleston, South Carolina and the detail to which it was performed and reported was tailored specifically to the conditions at this facility. This report or the procedure associated with its formation is not intended to be a standard for inspections or reports covering other activities. Attempts are being made, however, toward establishing standards for procedures and formats for inspection and assessment reports. Through these standards, inspections performed by different persons, on many facilities and under a wide range of conditions can be effectively compared. It is expected that the inspections and assessments of the Naval Weapons Station facilities, like previous operations mandated under the underwater portion of the Specialized Inspection Program, will contribute significantly toward achieving that objective.

It should be noted that the choice of the level of inspection and the procedural detail to be employed will be an engineering judgement made separately for each activity/facility to suit its unique situation and needs. Accordingly, the procedures used at the Naval Weapons Station, rather than serve as a detailed model for inspections elsewhere, will provide guidance with general applicability to future inspections.

EXECUTIVE SUMMARY

The objective of the underwater facility assessments conducted at the U.S. Naval Weapons Station in Charleston, South Carolina is to provide a generalized structural condition report of the designated facilities within the activity. These facilities are Wharf ALPHA, Pier BRAVO and Pier CHARLIE. Each facility was inspected by a team of engineer/divers using a combination of visual/tactile and ultrasonic techniques. Critical elements were photo-documented.

Wharf ALPHA and Pier CHARLIE appear to be in excellent condition, except for some localized structural damage or environmental deterioration. Wharf ALPHA has some cosmetic spalling on several piles. It is recommended that these areas be patched with an epoxy grout to insure adequate protection of the prestressed reinforcing steel. In Pier CHARLIE, one pile has suffered damage due to impact. It is recommended that the pile also be repaired. Loadings in the vicinity of this pile should be limited to dead load only, until repairs are performed.

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Refer to the following Executive Summary Table for an overview of each facility's construction and recommendations.

NAVAL WEAPONS STATION
CHARLESTON, SOUTH CAROLINA

EXECUTIVE SUMMARY TABLE

<u>Facility</u>	<u>Year Built or Modified</u>	<u>No. of Vertical Bearing Piles</u>	<u>No. of Batter Piles</u>	<u>Facility Size</u>	<u>Structure</u>
Wharf ALPHA	1968	1056	270	Main Pier - 1100'x75'; plus three approach piers, a fragmen- tation barrier, and two utility areas	18" square pre stressed co piles. Also, s concrete-encas steel H-piles
Pier BRAVO	1953	462	170	Main Pier - 732'x51'; Approach Pier - 239'x24'	Concrete-encas steel H-piles (HP12x53)
Pier CHARLIE	1964	166	56	Main Pier - 163'x99'; Approach Pier - 524'x21'	18" square and 21" wide octag precast, prest concrete piles

NAVAL WEAPONS STATION

CHARLESTON, SOUTH CAROLINA

EXECUTIVE SUMMARY TABLE

<u>No. of Batter Piles</u>	<u>Facility Size</u>	<u>Structure</u>	<u>Recommendations</u>	<u>Est. Ccst of Recommen- dations</u>
270	Main Pier - 1100'x75'; plus three approach piers, a fragmen- tation barrier, and two utility areas	18" square precast, prestressed concrete piles. Also, some concrete-encased steel H-piles	Repair spalled areas on three piles with epoxy grout. Rein- spect wharf in seven years.	\$ 950
170	Main Pier - 732'x51'; Approach Pier - 239'x24'	Concrete-encased steel H-piles (HP12x53)	No repairs necessary	N/A
56	Main Pier - 163'x99'; Approach Pier - 524'x21'	18" square and some 21" wide octagonal precast, prestressed concrete piles	Repair damaged pile. Restrict loading to dead load only around pile.	\$3,500

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SECTION 1

INTRODUCTION

This report is a product of the Underwater Inspection Program conducted by the Ocean Engineering and Construction Project Office (FPO-1), Chesapeake Division, Naval Facilities Engineering Command (NAVFACENGCOM) under NAVFAC's Specialized Inspection Program.

This program sponsors task-oriented engineering services for the inspection, analysis and design and monitoring of repairs for the submerged portions of selected Naval Waterfront Facilities. All services required to produce this report were provided by Childs Engineering Corporation of Medfield, Massachusetts under Tasks No. 4 and 5 of Contract No. N62477-80-C-0102.

The efforts expended and costs required to perform these underwater facility inspections vary greatly with the size, age, kind and construction type of the facilities involved. Other factors peculiar to a particular facility or activity also have an important effect on inspection time and costs. These factors include:

- *Type and quantity of biofouling to be cleaned for different levels of scrutiny, both visual and with instruments;
- *Tidal range - area exposed at low tide for boat inspection;
- *Time and type of last inspection;
- *Local environmental factors - salinity, pollution level, temperature, etc., affecting rates of corrosion and marine life;
- *Function of the facility and the level of activity associated with that function.

1.1 TASK DESCRIPTION

The scope of work under Task No. 4 of the program required the inspection of the underwater portion of designated wharves

and piers located at the Naval Weapons Station in the Charleston Naval Complex in South Carolina. The quality of inspection had to be sufficient to provide an adequate general structural assessment of the facilities and to identify areas of sufficient damage and/or deterioration to warrant immediate repair or a future, more detailed investigation.

1.2 REPORT CONTENT

The report contains a description of inspection procedures, the results of the inspection and analysis of the findings, accompanied by pertinent drawings and photographs. Specifically, the inspection results include a description of the location, construction and function of each facility examined within the Weapons Station, its observed condition and a structural assessment of that condition. Recommendations for each facility, including cost estimates for any repair work, are also included. Structural assessment calculations and cost estimate breakdowns can be found in the Appendix. Also, as supplementary information, a brief description of the Naval Weapons Station is provided to define its location, mission, history, existing facilities, climate and hydrographic and topographic features.

SECTION 2

ACTIVITY DESCRIPTION

This section provides a general description of the Naval Weapons Station, which is one of eight commands within the Charleston Naval Complex in South Carolina. The description includes brief discussions of the Weapon Station's location, mission, history, existing facilities, climate, topography and hydrology. This information provides a more overall view of the activity and a perspective to accurately assess the structural conditions of the facilities inspected.

2.1 LOCATION OF ACTIVITY

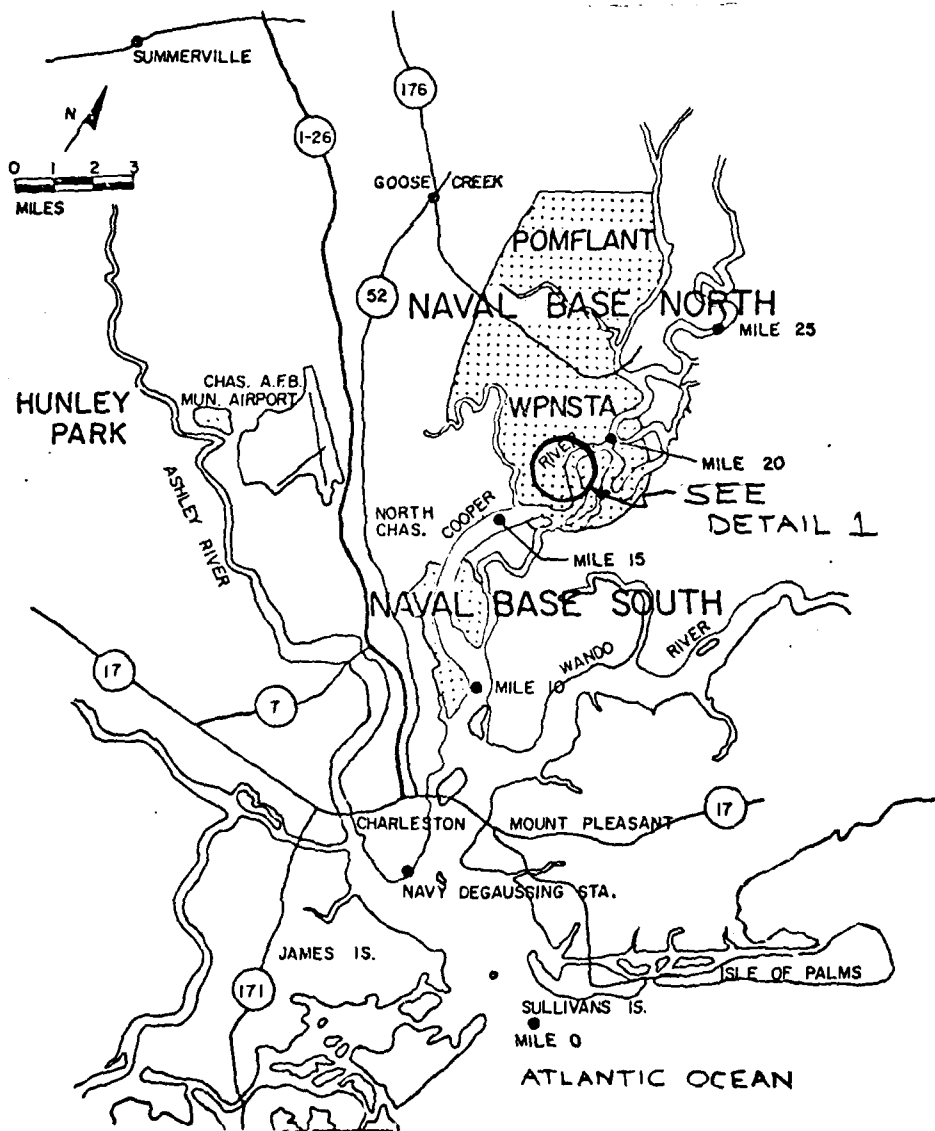
The Naval Weapons Station is located on the Atlantic seaboard approximately 20 miles north of the city of Charleston, South Carolina, in the southeast portion of Berkeley County. It is contained within the Naval Base North area of the Naval Complex and covers 16,600 acres. The Station lies on the west bank of the Cooper River, beginning approximately 15 miles upriver from the mouth of Charleston Harbor and continuing upstream for about 6 miles (see Figure 1).

2.2 MISSION OF ACTIVITY

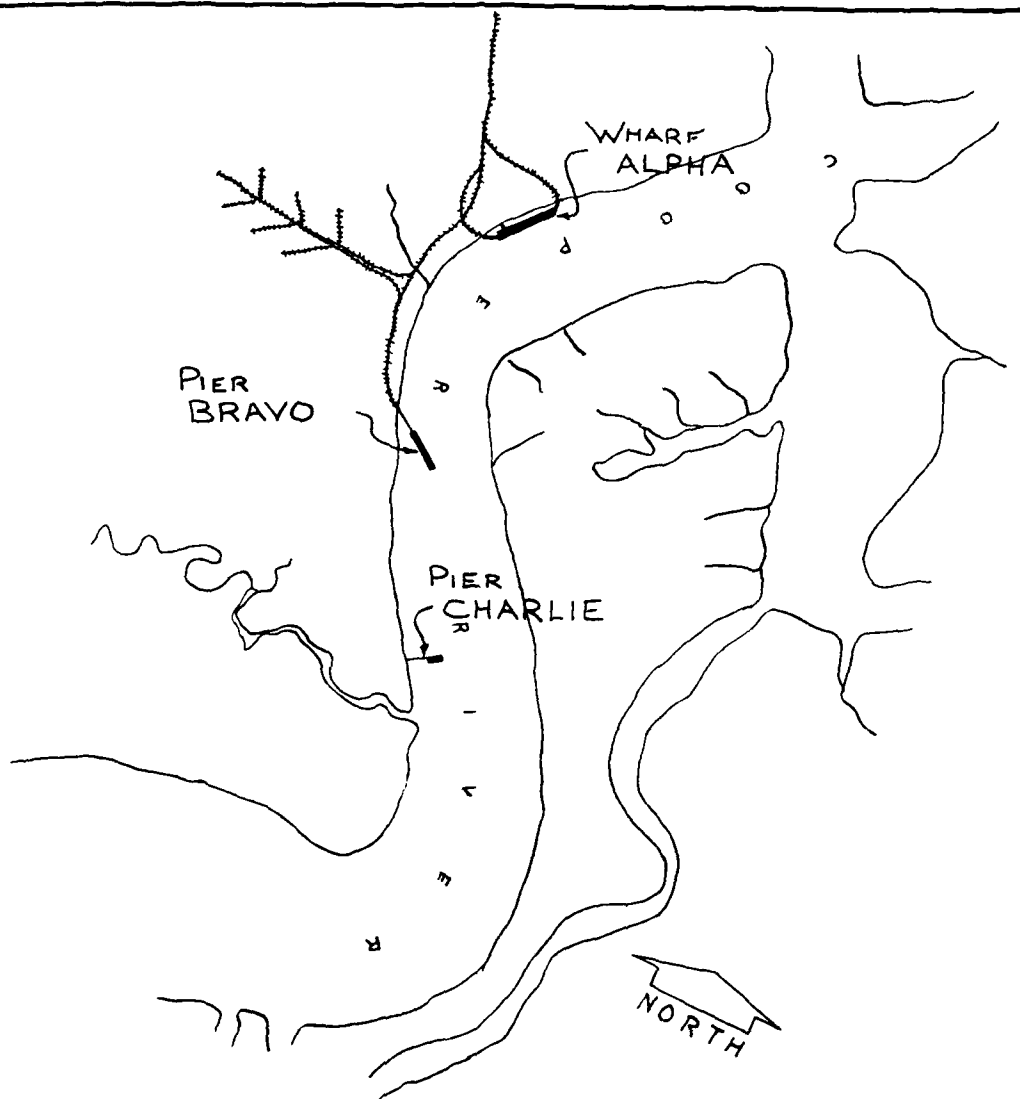
"The Station's primary mission is to provide material support for assigned weapons and weapons systems and to perform additional tasks as directed by the Commander, Naval Sea Systems Command. This includes supporting fleet and shore activities with guided missiles and conventional ammunition. Berthing and logistics support are provided for two ammunition ships (AF), a floating drydock (ARDM), a submarine tender (AS), and the FBM submarines assigned to Submarine Squadron 18. The number of submarines varies, but generally four are supported."

2.3 HISTORY OF ACTIVITY

"Established on November 5, 1941 as the U.S. Naval Ammunition Depot, the Station was engaged throughout World War II in receiving ammunition from assembly plants, stowing ammunition, performing upkeep on ammunition, and disposing of unserviceable stocks. In 1944 the Station acquired a mine test and issue capability.



FROM: MASTER PLAN, CHARLESTON NAVAL COMPLEX
 NAVAL FACILITIES ENGINEERING COMMAND, SOUTHERN DIVISION, 1978



DETAIL 1

GRAPHIC SCALE	Childs Engineering Corporation Box 355 Norfolk, VA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
N/A		NAVAL WEAPONS STATION CHARLESTON, SC	FIG. 1

CHESAPEAKE DIVISION, 1978

In 1945 the station began handling ammunition and components received from forces afloat and various shore-based activities in the South Atlantic area. A total of 377 ships and small craft were serviced at the Station between September 1945 and October 1946.

In 1949 the station mission was escalated to support the Atlantic Fleet Mine Force and the Marine Corps.

In 1952 after two years in a "maintenance" condition, the status of the Weapons Station was raised to "active" by the Secretary of the Navy.

Two years later the "Liberty Hall Annex" was acquired from the Army. This area contained 5,219 acres and is now known as the Polaris Missile Facility Atlantic.

In June 1956 the station established its first missile program known as the U.S. Naval Guided Missile Service Unit 213 which provided Navy and Marine Corps units with Terrier Guided Missiles."²

"The name of the installation was changed from U.S. Naval Ammunition Depot to Naval Weapons Station on September 1, 1965. The Weapons Station services and issues Terrier, Tartar, Standard, Hawk, and Redeye missiles; conventional ammunition; mines, torpedos; and anti-submarine weapons."³

2.4 EXISTING FACILITIES

Waterfront facilities at the Weapons Station include Wharf ALPHA, Piers BRAVO and CHARLIE (see Figure 1) and a mid-channel mooring for an ARDM. These facilities provide berthing for TAK supply ships, Fleet Ballistic Missile Submarines (SSBN), ammunition ships and the homeport for a Fleet Ballistic Missile Submarine Capable Tender (AS). Their railroad access and portal cranes allow them to load and unload strategic missiles, conventional ammunition and supplies. SSBNs can be tended on each side of the AS and can be refitted in the mid-channel ARDM.

2.5 CLIMATE

"In general the climate of the area is temperate, modified considerably by the nearness of the ocean. Monthly wind speeds average 9 mph with wind directions varying with the season. The area is subject to occasional hurricanes between July and September.

The area experiences no dry seasons although nearly 41% of the 49 inches of average annual precipitation occurs during the summer months. Thunderstorms are most frequent during the summer."⁴

Mean monthly precipitation ranges from a low of 2 inches to a high of 7.5 inches. Relative humidity ranges from an annual low of 57% to a high of 87%. Average annual sunshine is about 64% of maximum.

The annual temperature ranges from 55° to 75° F. with a mean of 62° F. Summer temperatures (June to August) range from 70° to 90° F. with an average of 80° F., while winter temperatures (December to January) range from 37° to 57° F. with an average of 47° F.

2.6 TOPOGRAPHY AND HYDROLOGY

"The Charleston Naval Complex is located in an area of very level topography. The maximum elevation of this area is approximately 35 feet above mean sea level. This level topography along with the rainy, humid climate of the region, produces many slow draining areas. Naval Base South tends to be swampy with little relief; on the other hand, Naval Base North has an abundance of fresh water ponds and extensive forests."⁵ Ground water is found from 2 to 18 feet beneath the surface.

"The basic flood used for Navy planning is the 100 Year Flood. This identifies an elevation that rising water is expected to reach once in every 100 years. The 100 year flood plain for the Charleston area is 10 feet above mean sea level. All buildings containing materials dangerous to the public, residential buildings, and buildings needing a high degree of protection must be sited above the 100 year flood plain."⁶

Almost all the land within Naval Base South lies below the 100 year flood plain, making it nearly impossible to comply with this siting restriction. However, Naval Base North contains considerable usable area above the 100 year flood plain.

Although the Weapons Station is located between 15 and 20 miles upstream from the mouth of Charleston Harbor, it is

tidally influenced and is estuarine in character. Tidal ranges for the Weapons Station are as follows:

	<u>Feet</u>
MEAN LOW WATER	0.0
MEAN TIDE LEVEL	2.6
MEAN TIDE RANGE	5.2
SPRING TIDE RANGE	6.1

The Weapons Station apparently does not require regular dredging as the river current sweeps the bottom clean in this area. The river channel is maintained at a depth of 37 feet below mean low water.

SECTION 3

INSPECTION PROCEDURE

Between March 23 and April 3, 1981, a team of one engineer and two technicians, all certified SCUBA divers, performed an on-site underwater inspection of selected piers at the Naval Weapons Station, Charleston, South Carolina. The level of inspection to be performed, the type of structure being inspected, actual on-site conditions and past experience, combined with a thorough knowledge of engineering theory, dictated the inspection procedures that were followed.

3.1 LEVEL OF INSPECTION

The inspection techniques used had to be sufficient to yield information necessary to make a general condition assessment of the supporting structure of each facility, identify any areas that were mechanically damaged or in advanced states of deterioration, and formulate repair and maintenance recommendations and cost estimates. In general, this meant utilizing visual/tactile inspection techniques, accompanied by occasional external measurements employing such instruments as a scale, calipers or ultrasonic steel thickness gauge, where appropriate. Photographic documentation of typical as well as notable or unusual conditions was also obtained.

3.2 INSPECTION PROCEDURE

The scope of work for Task No. 4 required that one wharf and two stationary piers at the Naval Weapons Station be inspected from the splash zone (practically speaking, the pile cap) to the mudline for general conditions and any gross structural damage or deterioration. The fender and utility systems were beyond the scope of this inspection.

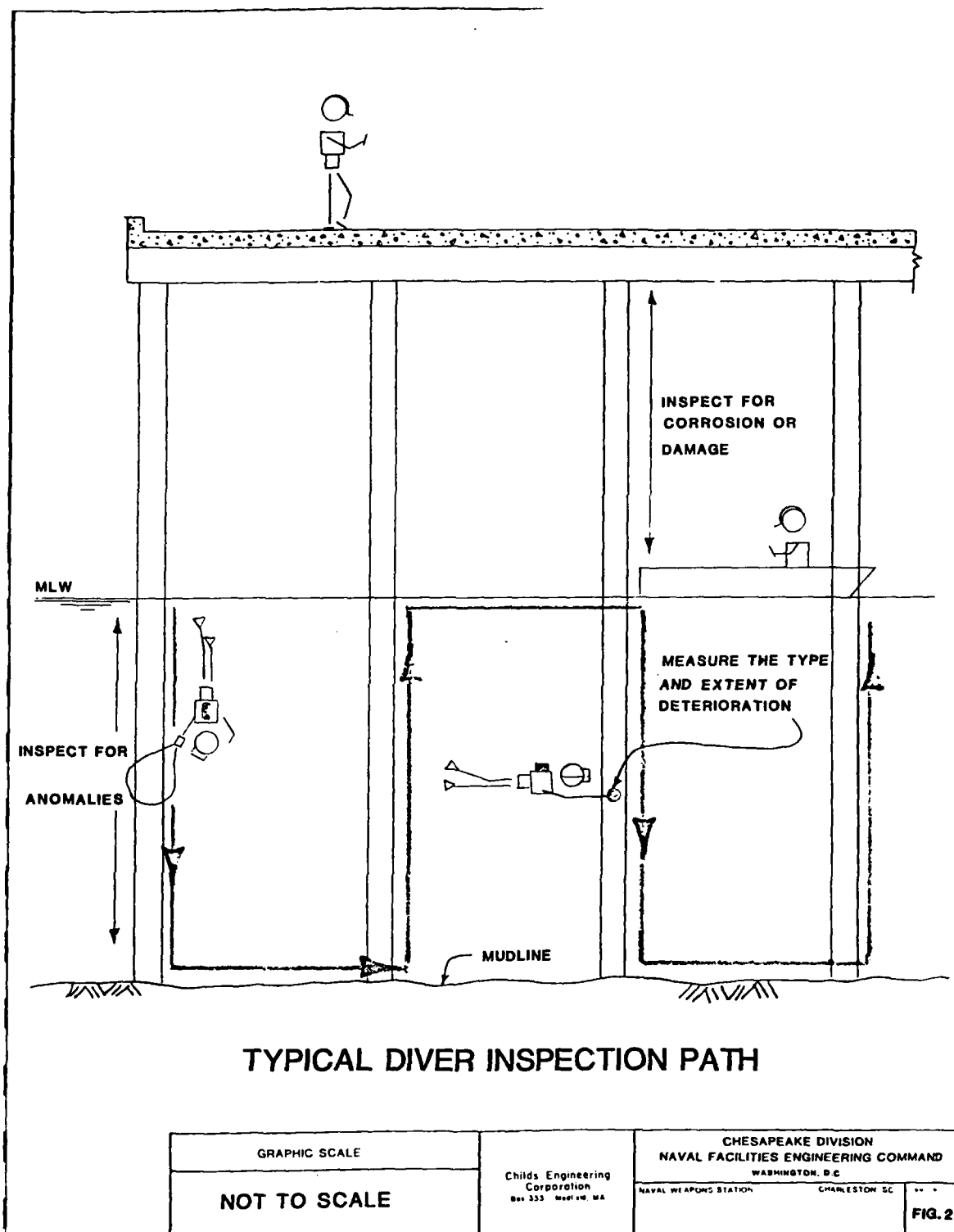
A dive team consisting of two divers and one tender/notekeeper performed the on-site inspection. Past experience has proven

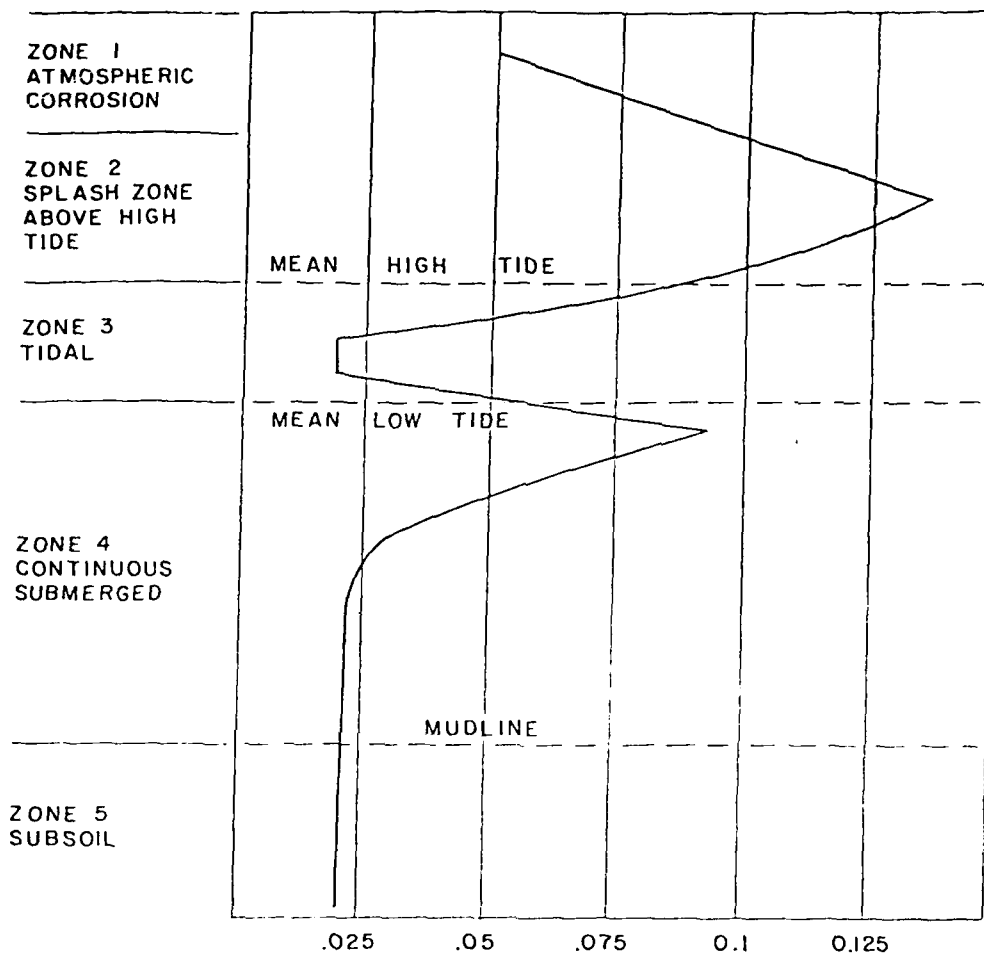
this arrangement to be efficient as well as safe. Depending on the layout of the piles, divers would either inspect alternate bents or each take a portion of a bent. A minimum of 20% of the piles of each facility were closely inspected from the pile cap to mudline. The remainder of the piles were given a more cursory "swim-by" inspection, normally at mean low water as much of the damage or deterioration was seen in this area. Usually, every fifth bent was inspected closely in a manner similar to that depicted in Figure 2. Soundings were taken at intervals around the perimeter of each facility.

Often it was necessary to remove marine growth and/or corrosion from some surface areas of selected piles for an adequate structural assessment. Small patches were frequently cleared during a close inspection. If the piles were steel, ultrasonic thickness readings were taken in the cleaned area.

For facilities with reinforced concrete piles or concrete-encased steel piles, inspection involved the noting of any cracking, spalling or rusting. Piles were hit with a hammer to gauge the soundness of the concrete and any softness that might be present. If any portion of the steel pile was exposed in a concrete-encased steel pile, the condition of the steel was noted, and in certain cases, metal thickness was gauged.

For facilities with exposed steel piles, corrosion of the metal was an important concern. Based on classical corrosion curves, as shown in Figure 3, areas of maximum corrosion usually occur at or around mean low water (MLW), within 2 feet of the mudline, in the splash zone and in areas where a differential oxygen concentration cell is set up. This latter case can occur at the interface or boundary areas between concrete and steel.





RELATIVE LOSS IN METAL THICKNESS
CORROSION PROFILE OF STEEL PILING - FIVE YEARS EXPOSURE IN SEAWATER

FROM: S. C. FYRE, "THE PROTECTION OF PILING" IN DESIGN
AND INSTALLATION OF PILE FOUNDATIONS AND CELLULAR
STRUCTURES, ED., HSAI - YOUNG FANG AND THOMAS D. DISMUKE
(PENNSYLVANIA: ENVO PUBLISHING CO., INC 1970) PP 191-207.

GRAPHIC SCALE	Childs Engineering Corporation Box 333 Medford, MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
N/A		NAVAL WEAPONS STATION CORROSION PROFILE FOR STEEL PILES	CHARLESTON, SC 3

As a result, the steel adjacent to the concrete is sacrificed to protect the steel under the concrete.

To document the corrosive activity, corrosion profiles were taken on selected piles. Small areas of the pile were cleaned to bare metal at selected elevations, and metal thickness was measured with an ultrasonic thickness gauge and/or calipers. The number of readings taken per pile and the number of piles measured per facility were based on profiles previously obtained and on experience.

It should be noted that during our investigation no destructive testing was performed. The conditions noted reflect direct observation or measurement of structural components which were accessible. Information which may infer knowledge of conditions of hidden components are based on government-furnished documents, our knowledge of structures in similar environments and/or generally accepted engineering theories.

3.3 INSPECTION EQUIPMENT

Equipment used for the inspection included a Krautkramer D-meter ultrasonic steel thickness gauge with DMR probe and 75 feet of cable, a Minolta SRT 200 camera with 28mm and 50mm lenses and strobe, Nikonos III underwater camera with Nikon closeup lens and a 7"x9" stainless steel framer, water box (for use in low visibility conditions) and strobe, dive lights, 100-foot sounding tape, 50-foot cloth tape, 6-foot folding rule, calipers, chipping hammers and dive knives.

Choice of equipment was made as a result of past experience. Most of the equipment is straightforward, easy to handle, carry and use, and has proven reliable under hard use.

Ultrasonic steel thickness gauging is preferred over other techniques (such as drilling test holes) since it is non-destructive, easy to handle, fast and reasonably accurate.

SECTION 4

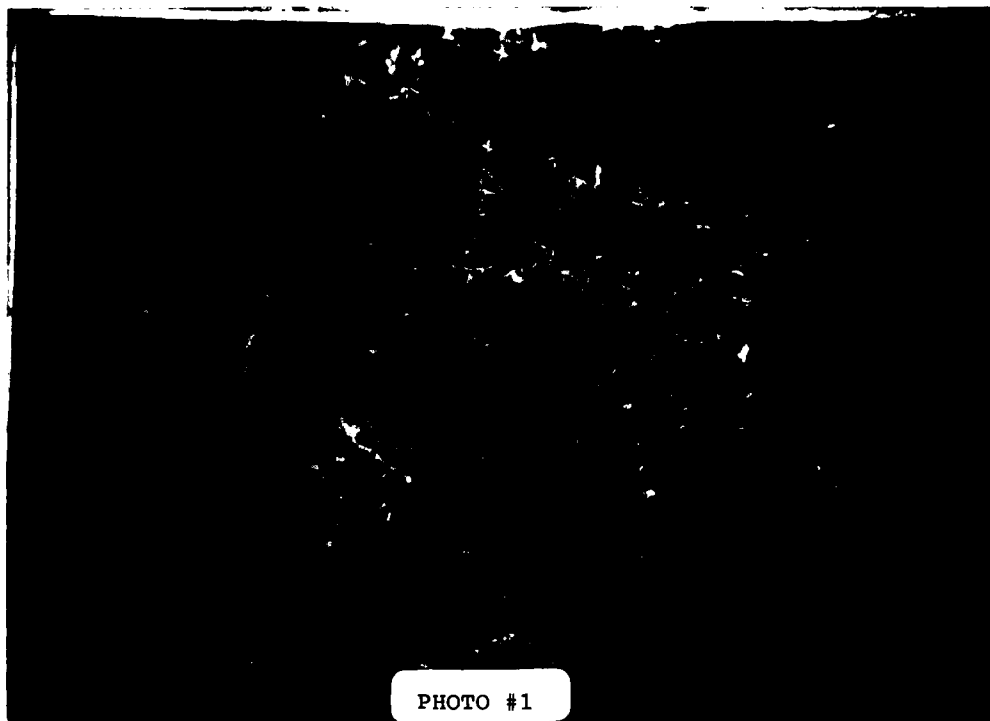
FACILITIES INSPECTED

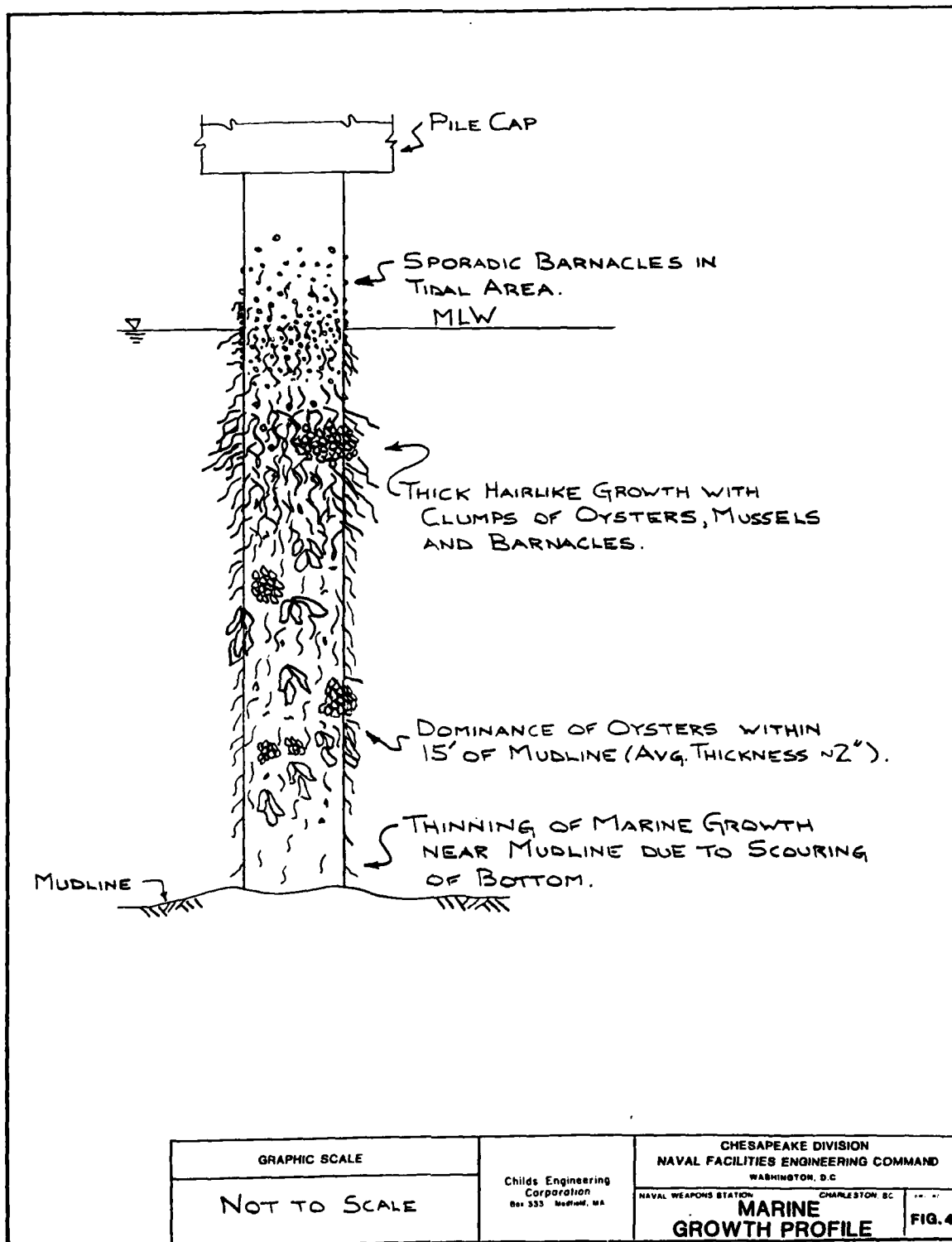
Within this section of the report, each facility inspected at the Naval Weapons Station is referenced separately. The discussion of each facility is presented in four parts: 1) a description of the construction and function of the structure, which is derived both from the on-site inspection and from the referenced government-furnished drawings; 2) an enumeration of general and specific conditions observed during the on-site inspection; 3) a qualitative assessment of the structural condition of the facility based on the inspection data; and 4) recommendations for actions to be taken to insure long-term, cost-effective maintenance and utilization of the facility. Detailed breakdowns of cost estimates are included in the Appendix.

Marine growth profiles were noted for each facility. These profiles were similar for all facilities at the Weapons Station. In general, oysters, mussels and barnacles, along with a thick mat of hairlike growth covered the piles from mean low water to mudline (see Photo #1). Growth often thinned out within 6" - 12" of mudline, probably due to scouring. The hairlike growth was thick, particularly at Pier BRAVO where it was up to 3 feet long around mid-height on the piles. Oysters dominated in the area from mudline up 15 feet or so, and averaged in thickness around 2". Growth thinned out above mean low water to a sparse covering of barnacles which ended in the splash zone. Figure 4 illustrates the general growth pattern.

The phrase "cosmetic spalling" is frequently used in this section. It is used to indicate surface spalling of concrete that does not affect the structural integrity of the structure.

Photo #1: Example of Marine Growth Observed at
Naval Weapons Station Around Mean Low
Water (Pier CHARLIE)





4.1 WHARF ALPHA

4.1.1 Description

Wharf ALPHA, the northernmost waterfront facility at the Naval Weapons Station, is a marginal wharf with two berths located on the west bank of the Cooper River. It is used to transship strategic missiles to TAK supply ships for shipment to overseas replenishment sites. It is also used for loading and unloading Fleet Ballistic Missile Submarines (SSBN). The wharf is provided with railroad and highway access and a 45-ton portal crane.

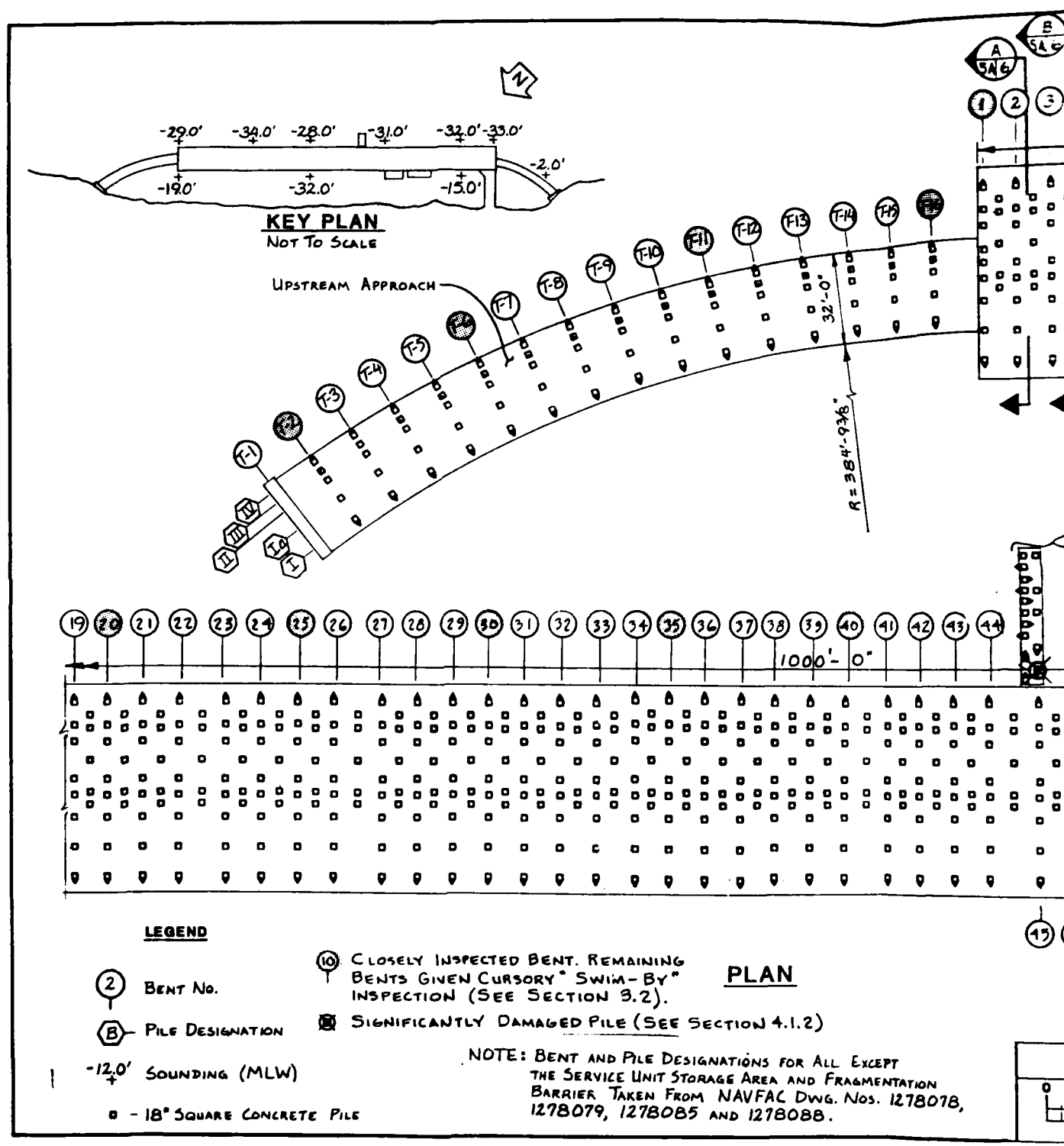
Wharf ALPHA was built around 1968 and consists of an 1100' long x 75' wide main wharf section of 87 bents, including a downstream vehicular access, and an upstream and a downstream approach, each 16 bents long (see Figures 5 & 6). The facility is supported mainly by 18" square prestressed, precast concrete piles. The exception to this is the downstream vehicular access in which four bents also have a mixture of circular and octagonal concrete piles. According to the government-furnished drawings, these piles are steel H-piles which have been encased in concrete to below the mudline. The piles on the approaches are designed for a 70-ton capacity, and those on the main wharf are designed for a 60-ton capacity.

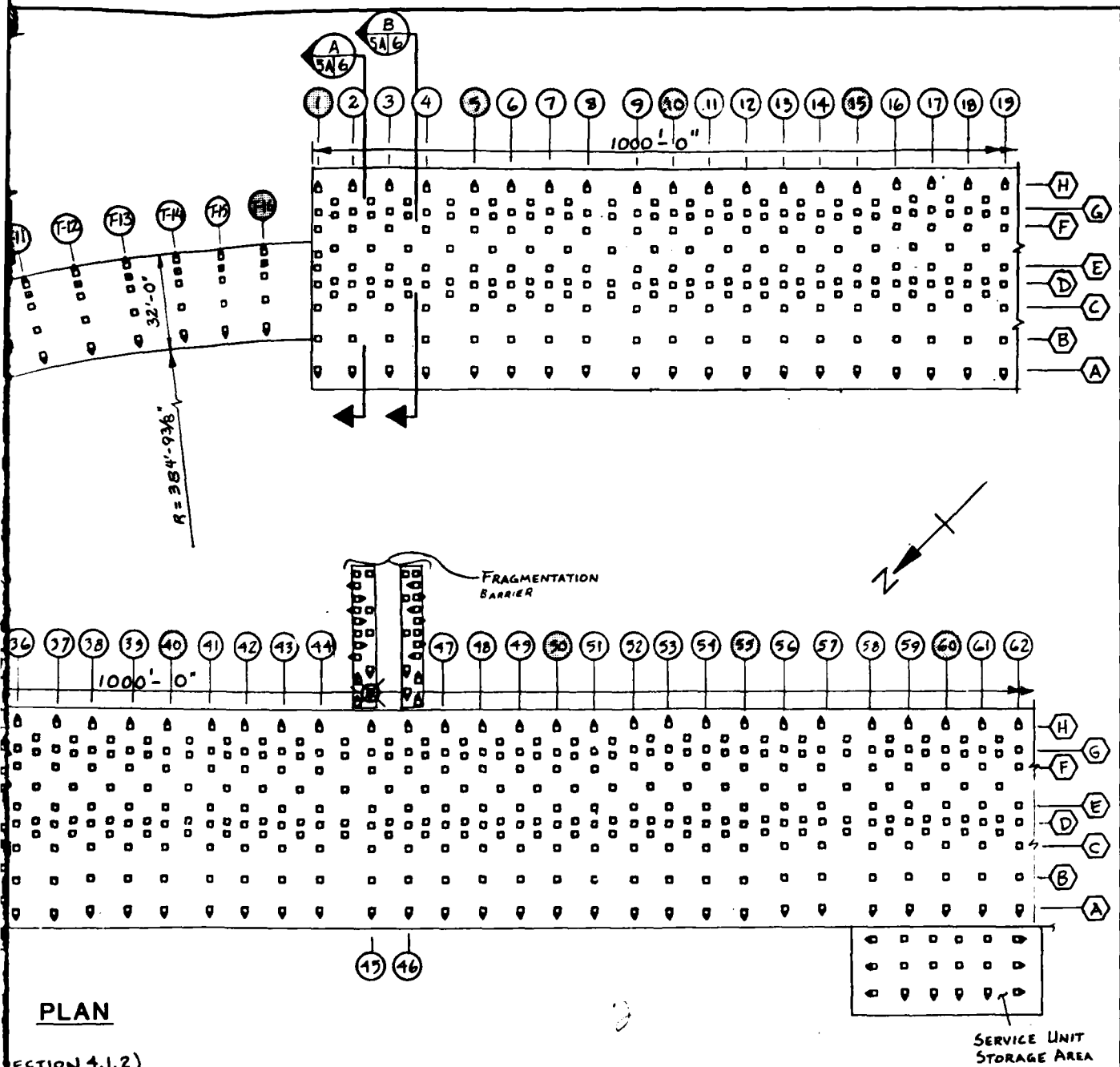
In 1977, a 30-foot wide service unit storage area was added next to the utility area on the inshore side of the main wharf, from Bents 58 to 62. At the same time, a 48-foot wide fragmentation barrier was added to the outshore side of the main wharf, between Bents 45 and 47. Both of these structures are supported by 18" square prestressed, precast concrete piles. Piles for the service unit storage area have a design capacity of 40 tons.

In all, there are 1326 bearing piles supporting the reinforced concrete decking, two sets of railroad tracks and one set of crane rail tracks.

References: Southeast Division, Naval Facilities Engineering Command
"Extension of Wharf ALPHA"
NAVFAC Dwg. #1278085, #1278088, #1278092
and #1278093

Southern Division, Naval Facilities Engineering Command
"Modifications and Additions to Wharf "A" "
NAVFAC Dwg. #5046120 and #5046124

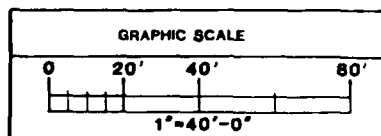




PLAN

SECTION 4.1.2)

NOTATIONS FOR ALL EXCEPT
STORAGE AREA AND FRAGMENTATION
NAVFAC DWG. Nos. 1278078,
AND 1278088.



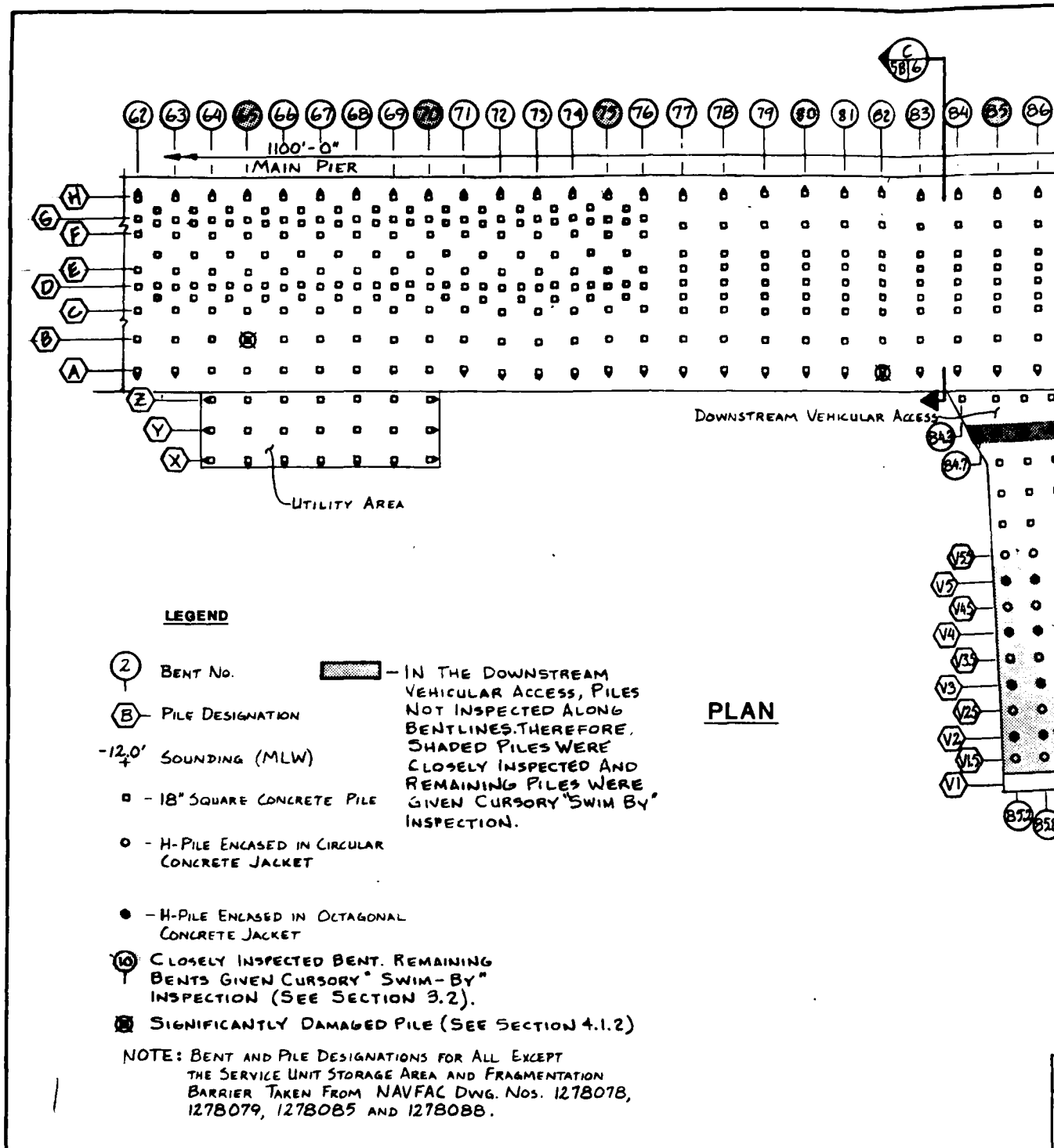
Childs Engineering
Corporation
Box 331, Weymouth, MA

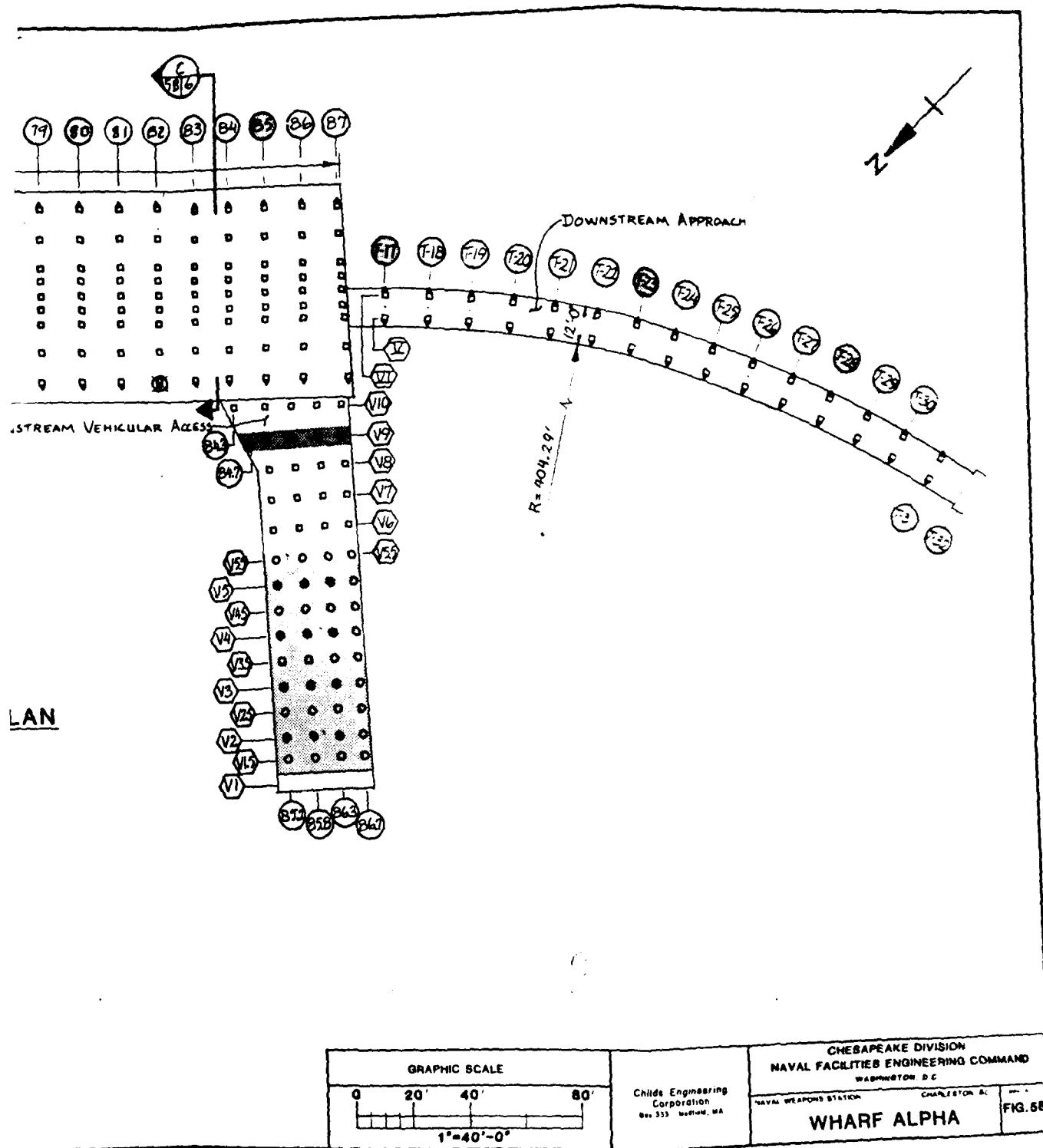
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D.C.

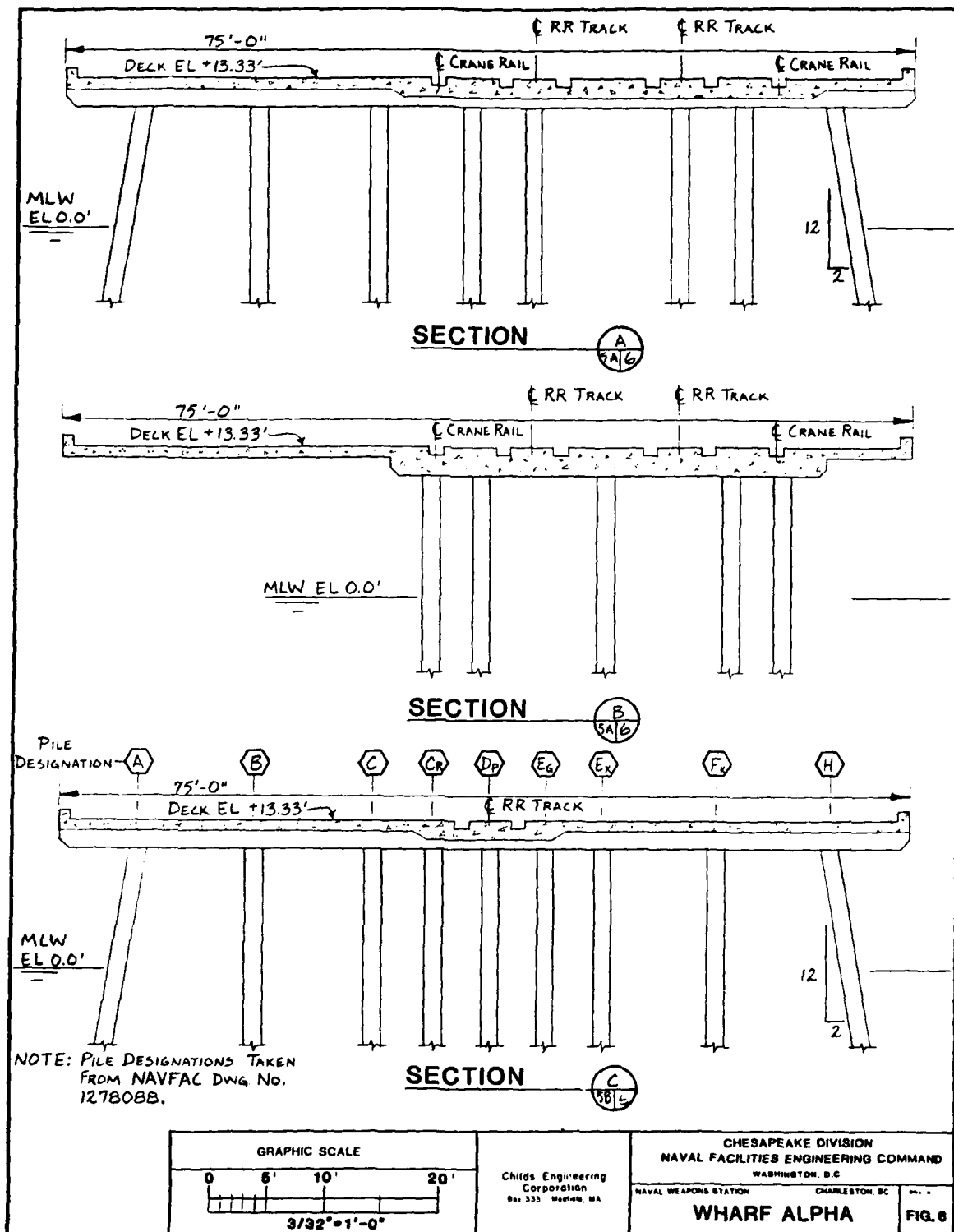
NAVAL WEAPONS STATION CHARLESTON, SC

WHARF ALPHA

FIG. 5A







4.1.2 Observed Inspection Condition

Throughout Wharf ALPHA, cosmetic spalling approximately 1/2" deep was observed on the corners of the precast, prestressed concrete piles. Also, the concrete on all piles appeared hard and durable.

In the downstream vehicular access, only the octagonal piles showed signs of structural deterioration. In these piles, cracks were observed between the pile cap and approximately 1 foot below mean high water. These cracks, approximately 1/16" wide and 1/2" deep, were present on all faces of the pile in this area (see Photo #2).

No structural irregularities were noted in the downstream or upstream approaches of the pier.

In the main wharf, three piles were observed to have areas of spalled concrete. They are described as follows:

<u>Bent</u>	<u>Pile</u>	<u>Elevation (from MLW)</u>	<u>Description</u>
82	A	-2.0'	3" diameter spalled area; no steel reinforcing exposed.
65	B	0.0'	Spalled area, 7" long and a maximum of 2" deep; no steel reinforcing exposed.
Fragmentation Barrier (See Figure 5)		-7.0'	18" high x 6" wide by a maximum of 2" deep spalled area; no steel reinforcing exposed.

Soundings taken at Wharf ALPHA can be seen in Figure 5. These soundings showed depths ranging from -28.0' to -34.0' below mean low water (MLW) along the outshore face of the main wharf area.

**Photo #2: Typical Crack (Less Than 1/4" Wide) in
Octagonal Concrete Pile on Downstream
Vehicular Access, Running from the Pile
Cap to Mean Low Water (Wharf ALPHA)**

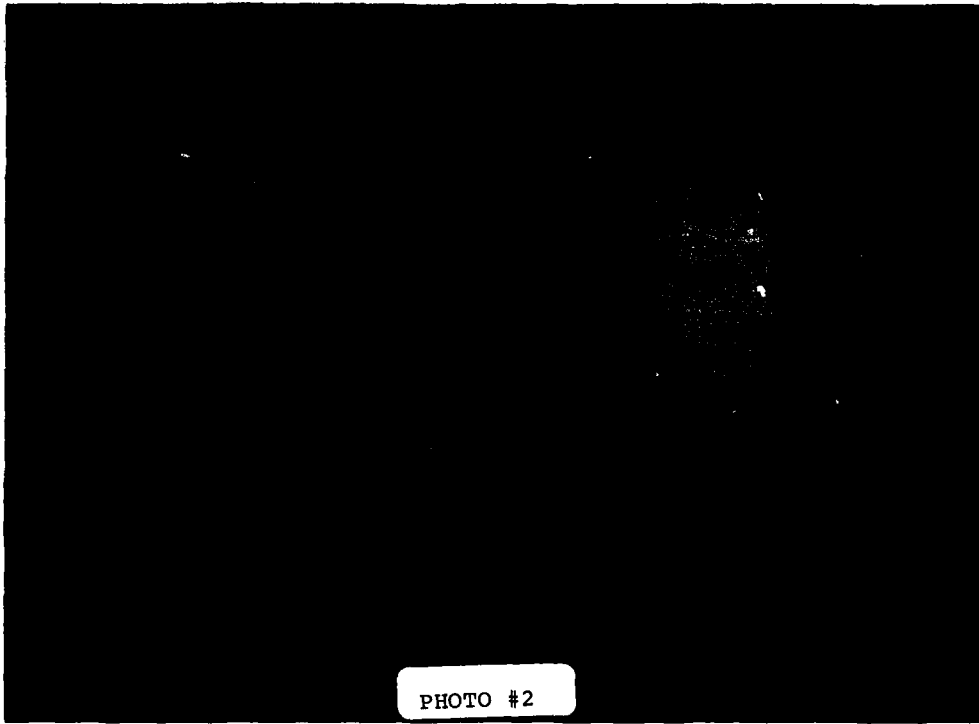


PHOTO #2

4.1.3 Structural Condition Assessment

Wharf ALPHA is in excellent condition. No structural deterioration was observed to cause the capacity of the wharf to be downgraded.

Three piles, however, have suffered some structural deterioration. These piles, located in the main wharf and mentioned in the previous section, have areas of spalled concrete which do not provide ample protection for the steel reinforcing from sea water infiltration.

The cracks noted in the octagonal piles in the downstream vehicular approach do not present a structural problem at this time. These concrete encasements are still providing ample protection for the steel H-piles, as no rust was observed around these cracks.

4.1.4 Recommendations

It is recommended that the spalled portions of the three piles in the main wharf be patched with an epoxy grout mix. Any more deterioration in these areas could expose the steel reinforcing to salt water corrosion. The estimated cost for repairing these three piles, based on using an underwater bonding epoxy grout at current prices, would be \$950.

It is also recommended that another inspection be performed in seven years to document any further deterioration. This report should be used as a reference for future inspections.

4.2 PIER BRAVO

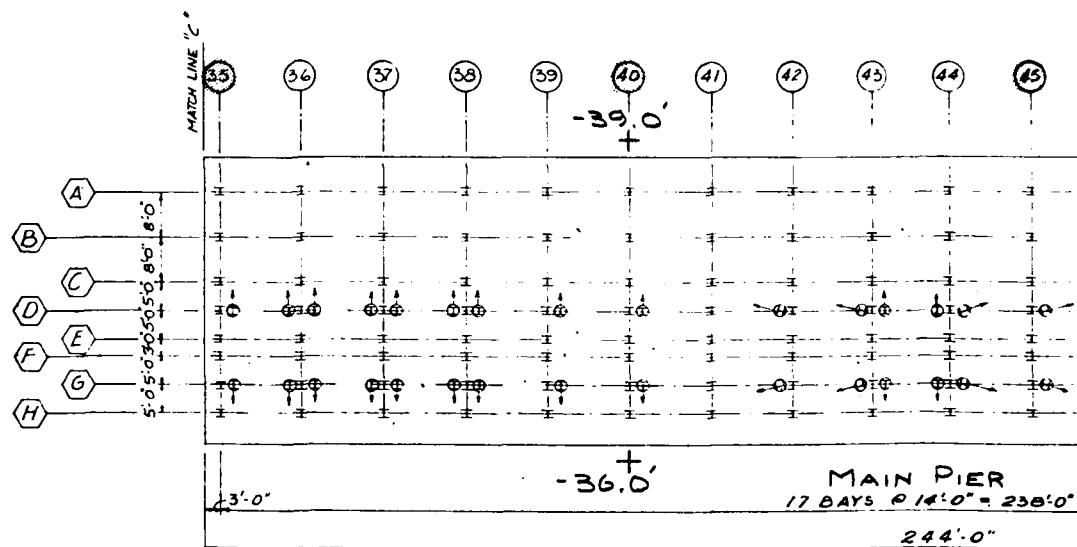
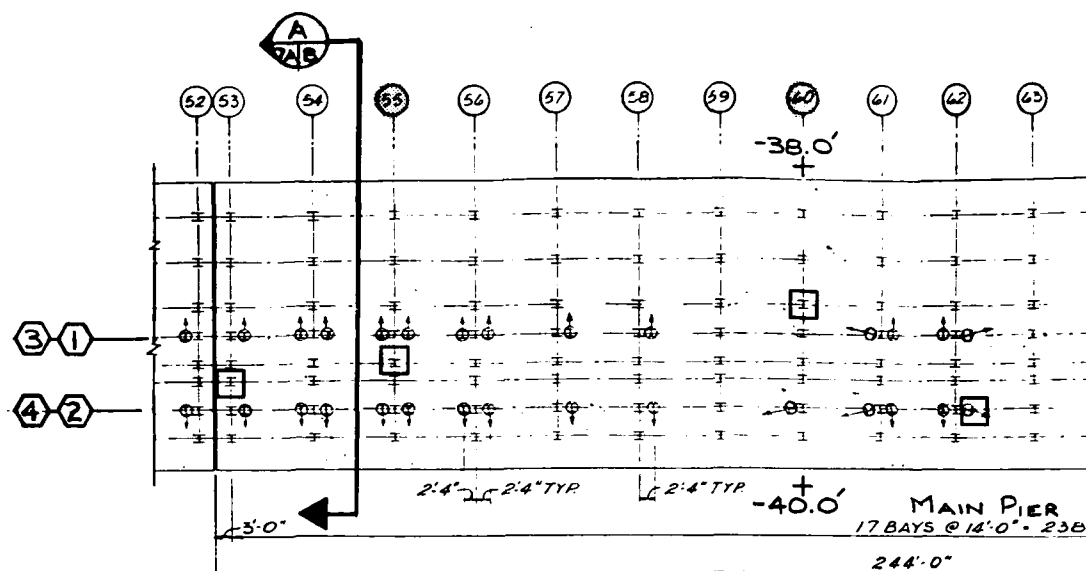
4.2.1 Description

Pier BRAVO, located just south of Wharf ALPHA on the west bank of the Cooper River, provides two berths that are used by ammunition ships (AE). It functions as one of the major outloading facilities for conventional ammunition to the Atlantic Fleet. The pier is provided with railroad and highway access and a 35-ton portal crane.

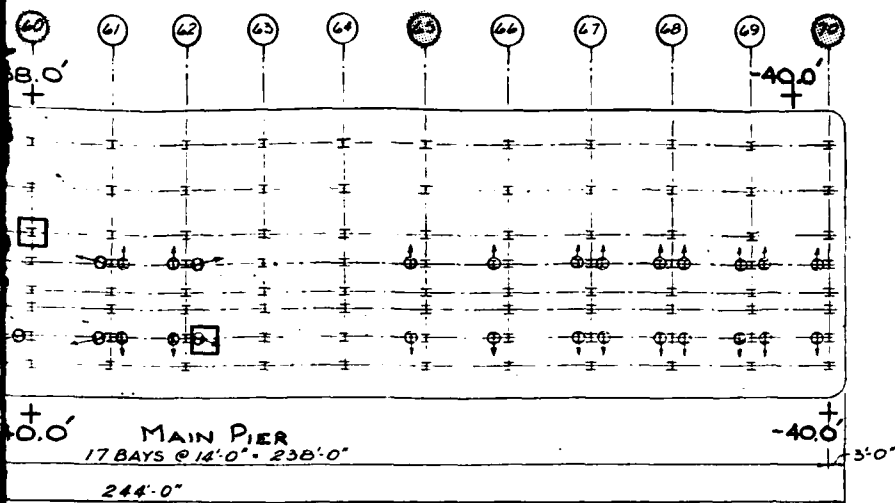
Pier BRAVO was built around 1953 and consists of a 732' long x 51' wide main pier, 54 bents long, and a 239' long x 24' wide approach pier, 16 bents long (see Figures 7A, 7B & 8). The reinforced concrete deck of the facility is supported by 632 steel H-piles, designated as HP12x53. Of these, 170 are batter piles (originally there were 174 but four have been cut off). Initially, these piles were encased with 20" square reinforced concrete jackets from the pile cap to -2.0' below mean low water (MLW). In 1972, the exposed H-piles were encased in 24" diameter concrete jackets from the base of the original jackets to approximately 4 feet below the existing mudline. The approach pier has a design live load of A.A.S.H.O. H-20-516-44, and the main pier has a design live load of A.A.S.H.O. H-20-S-16-14 or 500 PSF. Impact allowance is 20% of railway and crane loadings and A.A.S.H.O. for highway loadings. The piles are designed for a maximum bearing of 50 tons with no impact allowed, and the pier was designed for a dredge depth of -35.0' below MLW.

References: Bureau of Yards and Docks
"Reinforced Concrete Finger Pier"
Y&D Dwg. #599195 and #599197

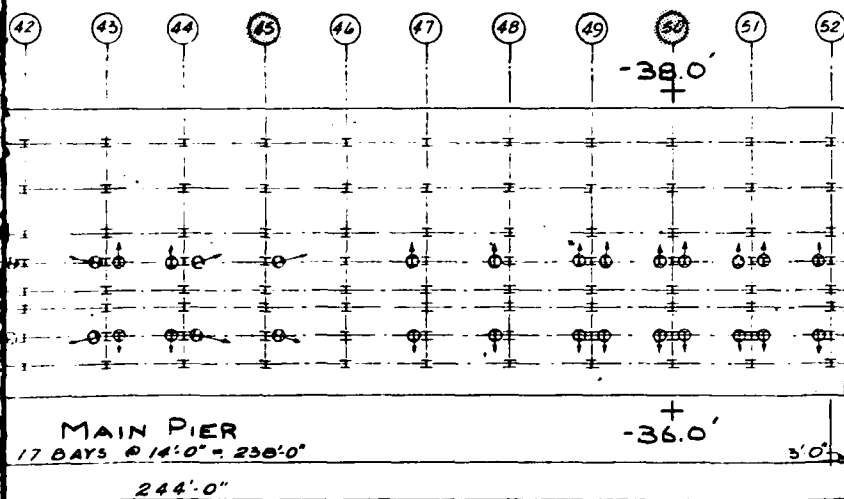
Southern Division, Naval Facilities Engineering
Command
"Repairs to Pier BRAVO"
NAVFAC Dwg. #5018268 and #5018271



FROM: NAVFAC DWG. NO. 501826B
SOUTHERN DIVISION
"REPAIRS TO PIER BRAVO - PILE LAYOUT - STRUCTURAL"

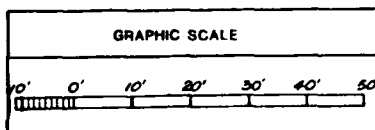


PILE PLAN



LEGEND

- Ⓐ - VERTICAL PILE DESIGNATION
- ② - BATTER PILE DESIGNATION
- Ⓔ - BENT No.
- 10.0' + - SOUNDING (MLW)
- Ⓔ - CLOSELY INSPECTED BENT. REMAINING BENTS GIVEN CURSORY "SWIM-BY" INSPECTION (SEE SECTION 3.2)
- Ⓔ - METAL THICKNESS READINGS TAKEN (SEE APPENDIX).

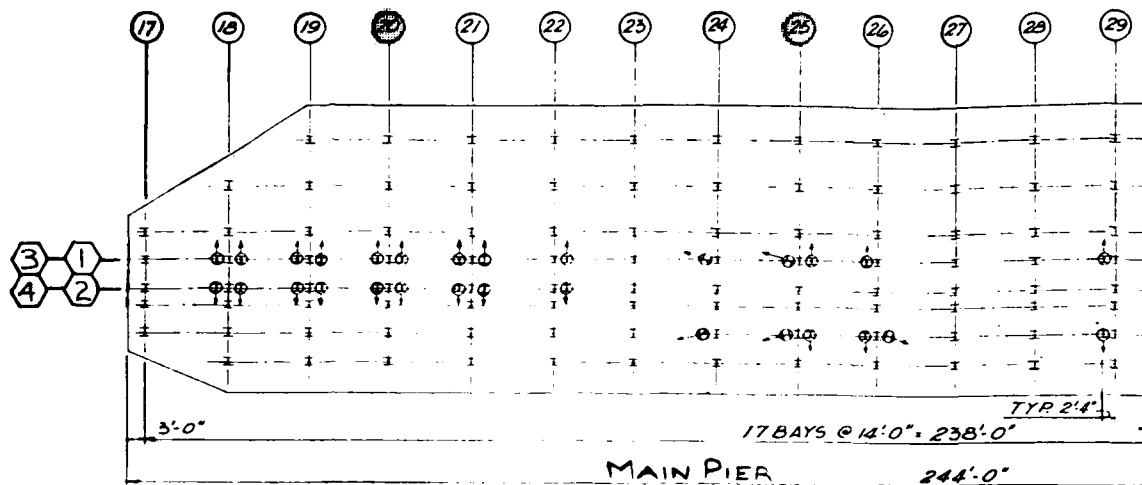


Childs Engineering
Corporation
Box 333 Bedford, MA

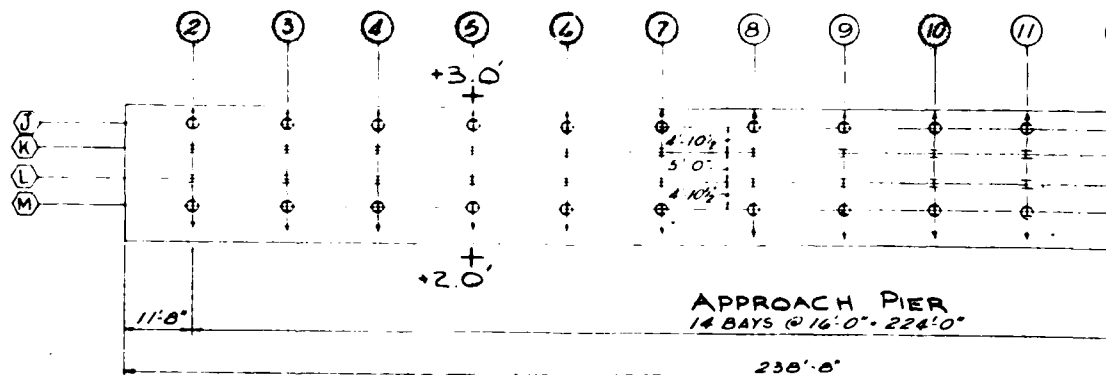
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D.C.
NAVAL WEAPONS STATION CHARLESTON, SC

PIER BRAVO

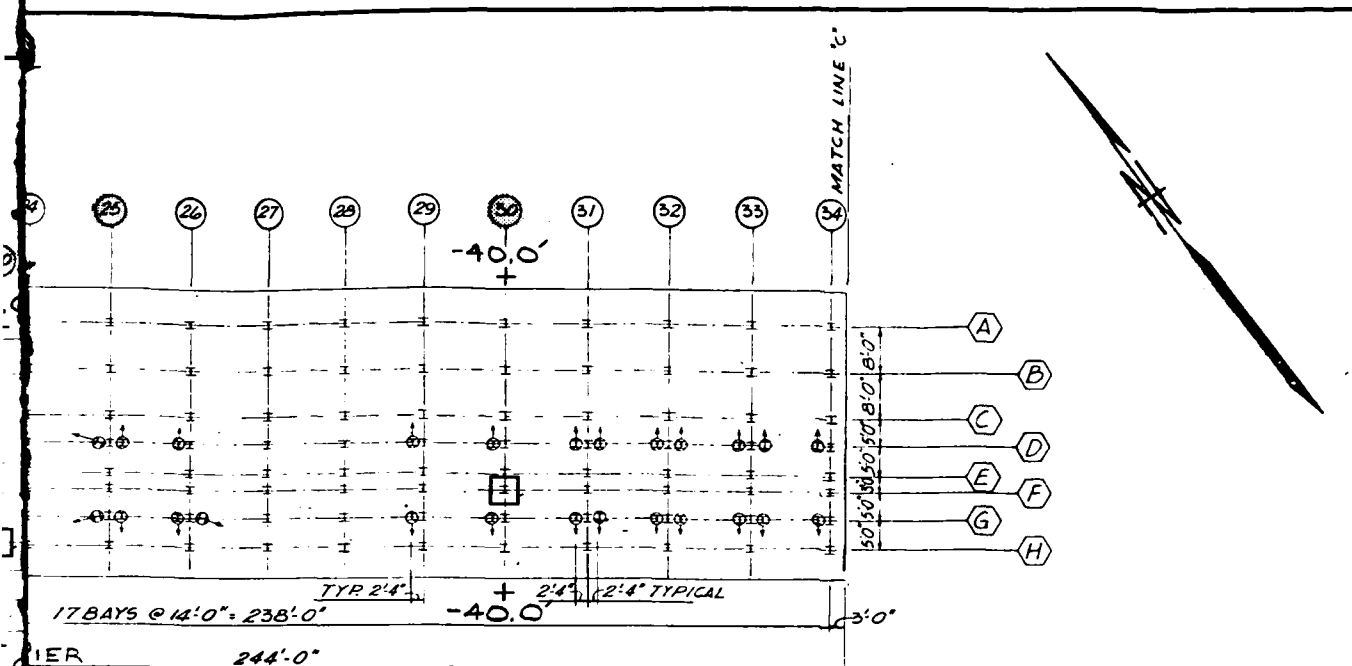
FIG. 7A



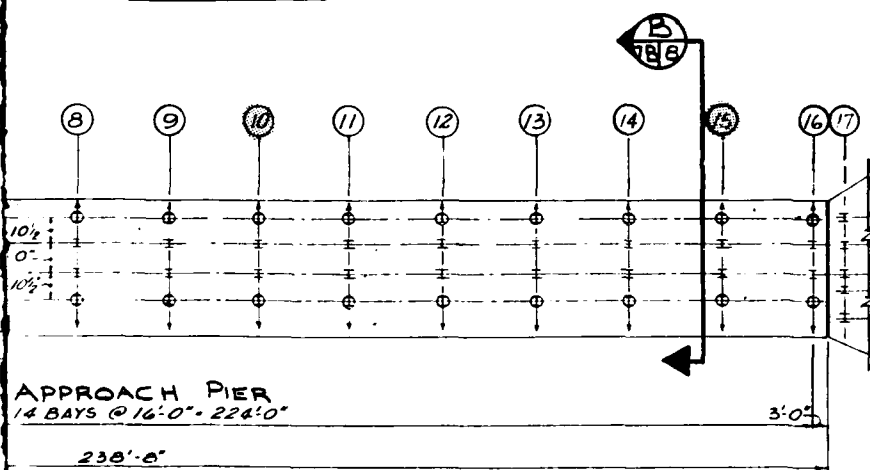
PILE PLAN



FROM: NAVFAC DWG. No. 5018268
SOUTHERN DIVISION
'REPAIRS TO PIER BRAVO-PILE LAYOUT-STRUCTURAL'

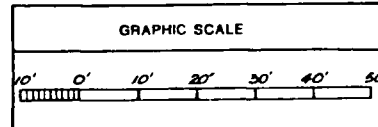


PILE PLAN

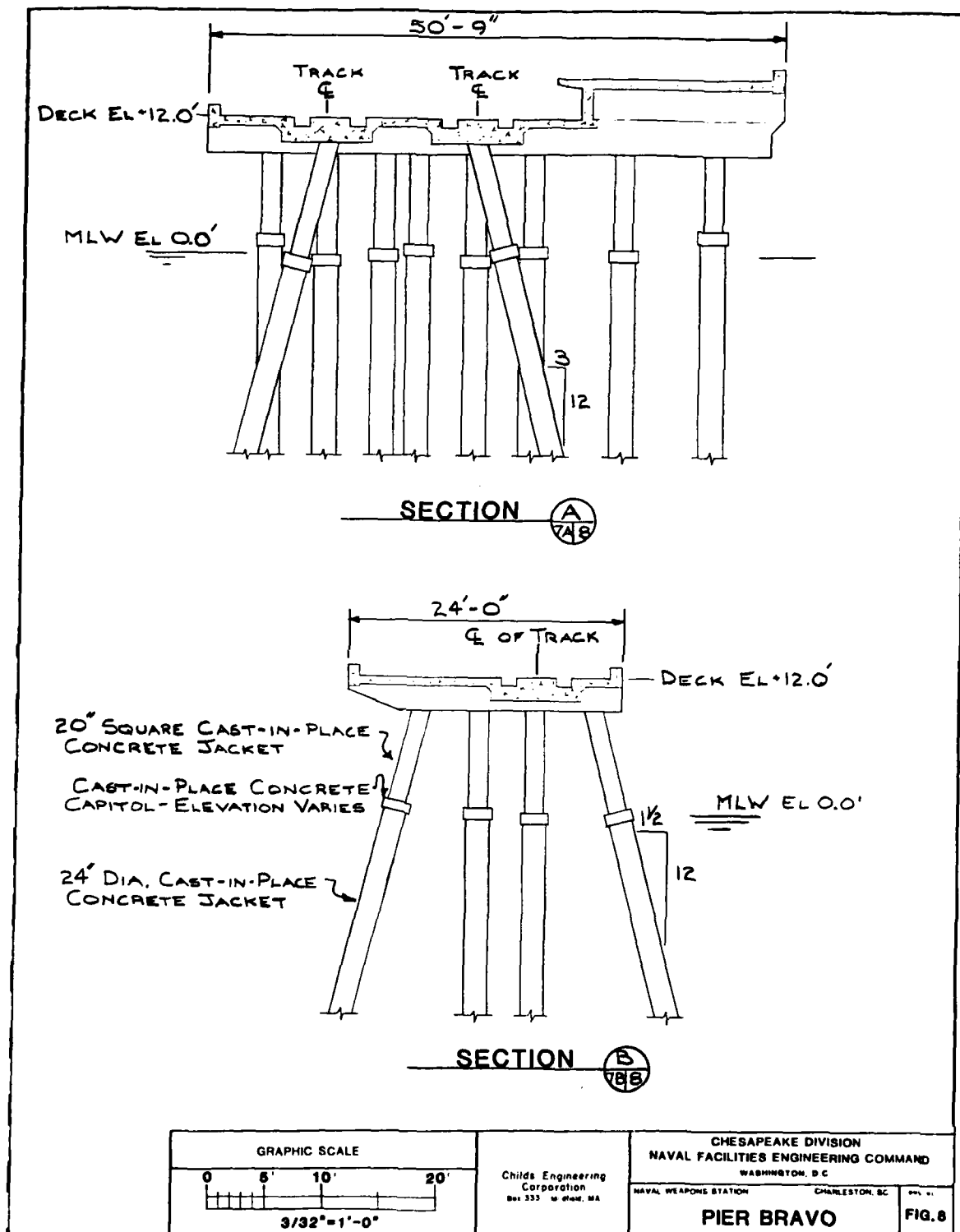


LEGEND

- (A) - VERTICAL PILE DESIGNATION
- (1) - BATTER PILE DESIGNATION
- (2) - BENT NO.
- 200' - SOUNDING (MLW)
- + -
- (5) - CLOSELY INSPECTED BENT. REMAINING BENTS GIVEN CURSORY SWIM-BY INSPECTION (SEE SECTION 3.2)
- [I] - METAL THICKNESS READINGS TAKEN (SEE APPENDIX).



Childs Engineering Corporation Box 333, Methuen, MA		CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
NAVAL WEAPONS STATION		CHARLESTON, SC	
PIER BRAVO		FIG. 7B	



4.2.2 Observed Inspection Condition

This section will be divided into three separate parts. The first part deals with conditions observed between elevation +2.0' above mean low water (MLW) and the pile cap. The second part deals with conditions observed between +2.0' and -4.0', and the last part deals with conditions observed between elevation -4.0' and the mudline.

Between the pile cap and elevation +2.0', cracks up to 1/8" wide were observed in the concrete jackets of all the piles. In approximately 33% of these piles, rusting through these cracks was observed or the steel reinforcing was exposed (see Photos #3 and #4). In some places, these cracks had been repaired with gunite. Generally, however, the gunite was not adherent to the concrete.

Between elevations +2.0' and -4.0', several types of deterioration were noted in the concrete jackets. First, on the approach pier, hourglassing of the concrete encasements and rounding of the corners were very pronounced (see Photo #5). Often the welded wire mesh was exposed. On the main pier, at the interface between the circular and square concrete jackets, varying degrees of spalling and cracking were observed. In 30% of the piles, steel reinforcing or the H-pile was visible (see Photo #6). Up to 1" of softness in the concrete was observed in the square jackets and up to 2" of softness was observed in the circular jackets.

Below elevation -4.0', all the concrete jackets had varying amounts of spalling and cracking. Generally, spalled areas and cracks were up to 4" deep. However, in 20% of the circular jackets, voids up to 10 feet high, encircling the whole pile were noted. In all cases, steel reinforcing and the steel H-pile were exposed (see Photo #7).

Figure 9 shows a composite of typical pile conditions found at Pier BRAVO.

Steel thickness measurements were taken on five pile flanges which were accessible for measurement. These readings indicated the remaining steel thickness to be between .220 and .430 inches.

In Bent 15, the concrete encasement of Pile M extended only to elevation -11.0', approximately 5 feet short of the mudline.

Soundings along the north and south faces of the main pier section indicated the water depth to be between -36.0' and -40.0' below MLW.

PHOTO # 3: Typical Cracking (Max. 1/8"
Wide) in Concrete Pile,
Running from the Pile Cap
to Mean Low Water, with
Rusting Evident (Pier BRAVO)



PHOTO #4: Typical Spalling (1" - 3"
Deep) on Corner of Concrete
Pile Near Pile Cap, with
Steel Reinforcing Exposed
(Pier BRAVO)



Photo #5: Hourglassing of Concrete Encasement Around
Mean Low Water, Exposing Steel Reinforcing
(Pier BRAVO, Bent 12, Pile J, Elevation 0.0'
(MLW))

Photo #6: Typical Gap in Concrete Encasement Near
Cast-in-Place Capitol, Exposing Steel H-Pile
Flange (Pier BRAVO)

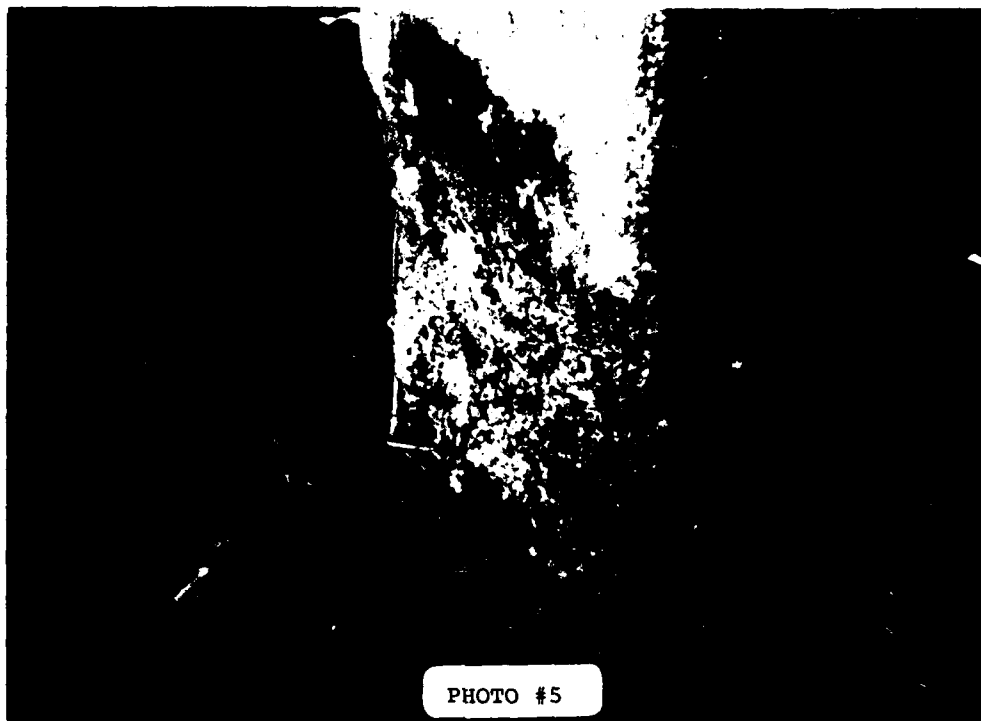


PHOTO #5

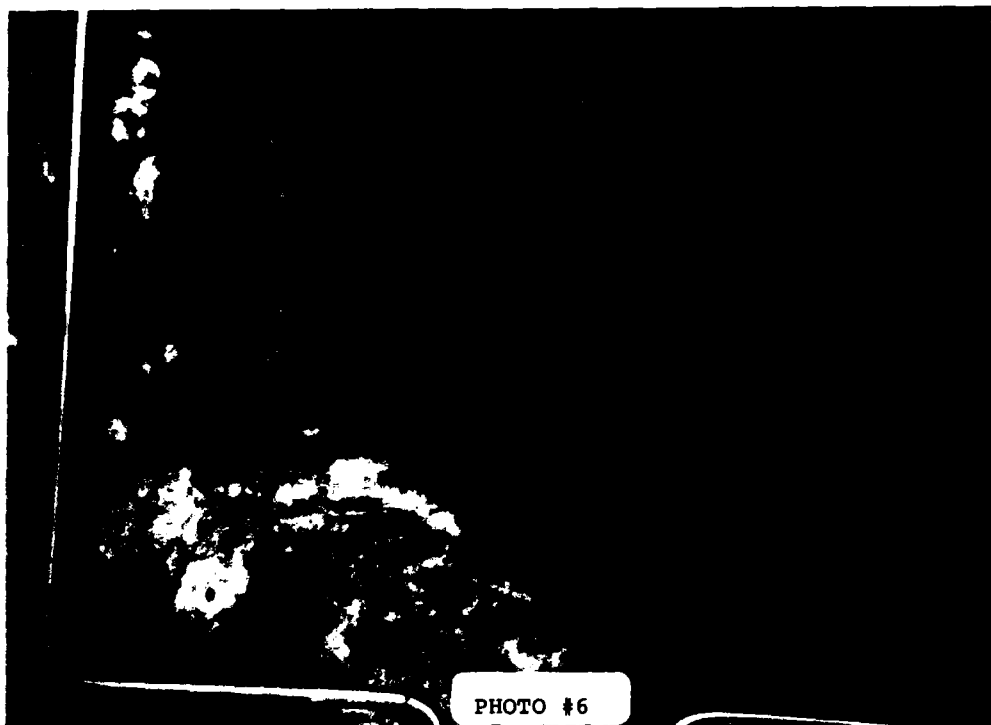
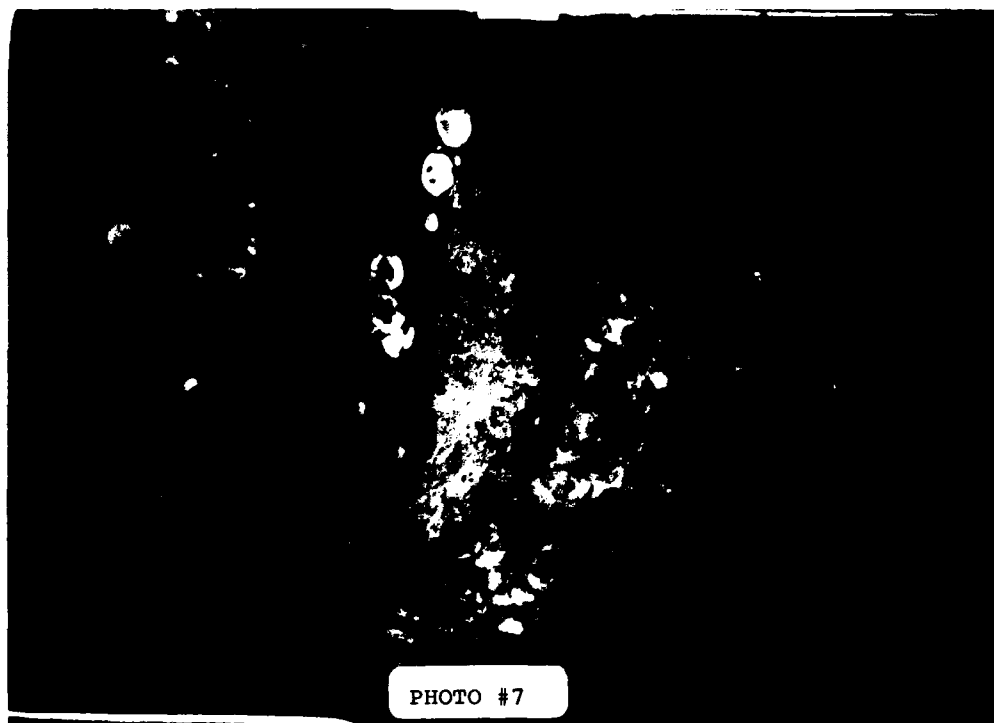
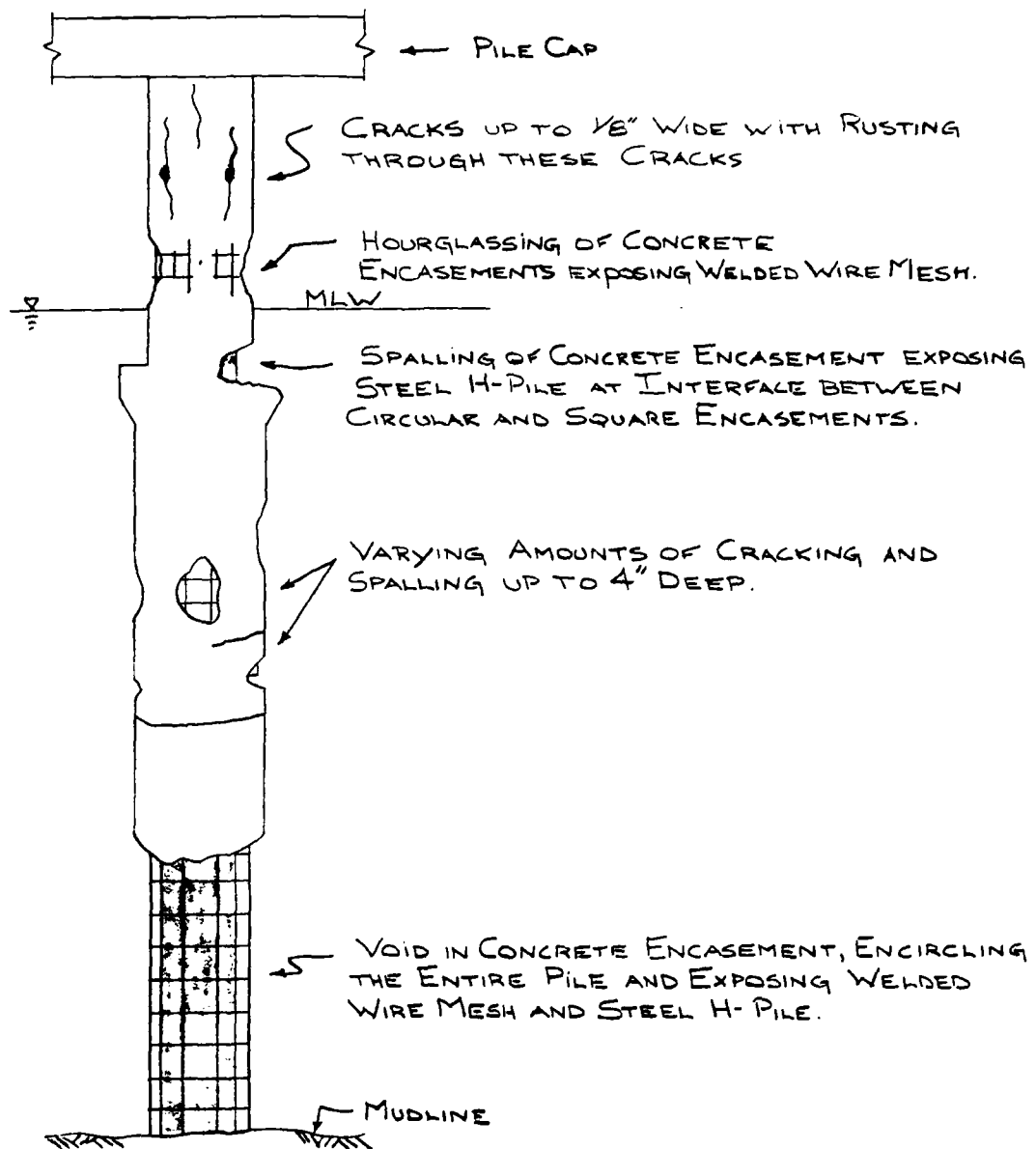


PHOTO #6

Photo #7: Typical Spalling of Concrete Encasement,
Exposing Wire Mesh and H-Pile (Pier BRAVO)





TYPICAL PILE CONDITIONS

GRAPHIC SCALE	Childs Engineering Corporation Box 333 Weymouth MA	CHESAPEAKE DIVISION NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON, D.C.	
NOT TO SCALE		NAVAL WEAPONS STATION PIER BRAVO	CHARLESTON SC 29405-01 FIG. 9

4.2.3 Structural Condition Assessment

All the concrete encasements on the steel H-piles of Pier BRAVO show varying amounts of deterioration, and in many places, the encasements are not protecting the piles from salt water corrosion. Steel thickness measurements indicate that in some areas up to 50% of the steel has been lost due to corrosion. However, based on structural analysis calculations, the pile foundation can still handle the imposed loads (see Appendix).

4.2.4 Recommendations

No repairs are recommended for Pier BRAVO at this time. However, Pier BRAVO should be reinspected in three years to document any further deterioration. This report should be used as a baseline for this future inspection.

4.3 PIER CHARLIE

4.3.1 Description

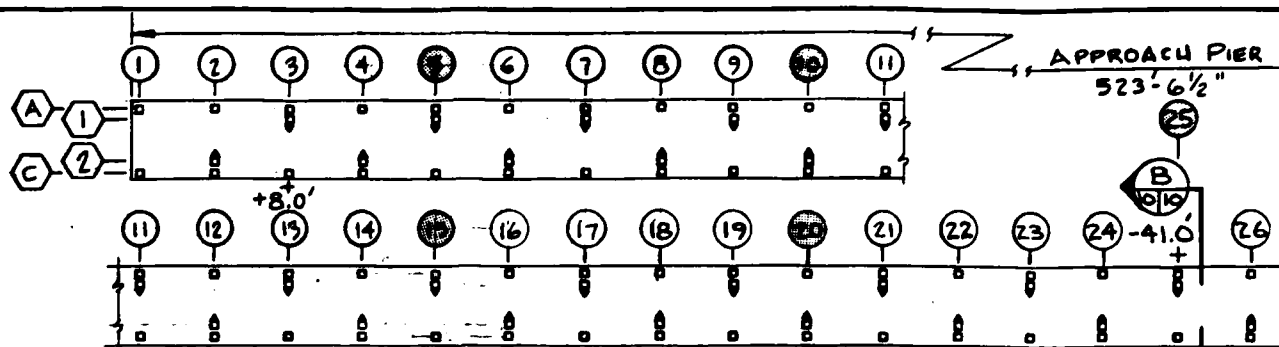
Pier CHARLIE, located just south of Pier BRAVO on the west bank of the Cooper River, serves as the Fleet Ballistic Missile Replenishment Site IV. As such, it provides the homeport for a Fleet Ballistic Missile Submarine Capable Tender (AS). The pier was designed to be a "Mediterranean Mooring" for the AS - i.e., the ship is moored "stern to" the pier, allowing SSBNs to be serviced on each side simultaneously.

Pier CHARLIE was built around 1964 and consists of a 524' long x 21' wide approach pier, 27 bents long, and a 163' long x 99' wide main pier, 9 bents long (see Figure 10). The approach pier and the upstream portion of the main pier are supported by 18" square precast, prestressed concrete piles. The downstream portion of the main pier is supported by precast, prestressed octagonal concrete piles (21" wide from opposite faces).

The main pier was extended inshore by two bents, probably in 1979 (this is the date marked on the heads of the piles). These piles are 18" square precast, reinforced concrete.

A total of 166 vertical and 56 batter piles serve as the foundation for the reinforced concrete decking of the facility.

References: Bureau of Yards and Docks
"FBM Replenishment Facilities - Pier - Plan
and Details"
Y&D Dwg. #1025502



(23) - BENT NO.

LEGEND

(A) - VERTICAL PILE DESIGNATION

(2) - BATTER PILE DESIGNATION

□ - 18" SQUARE PRECAST, PRESTRESSED CONCRETE PILE

○ - OCTAGONAL PRECAST, PRESTRESSED CONCRETE PILE

+ - SOUNDING (MLW)

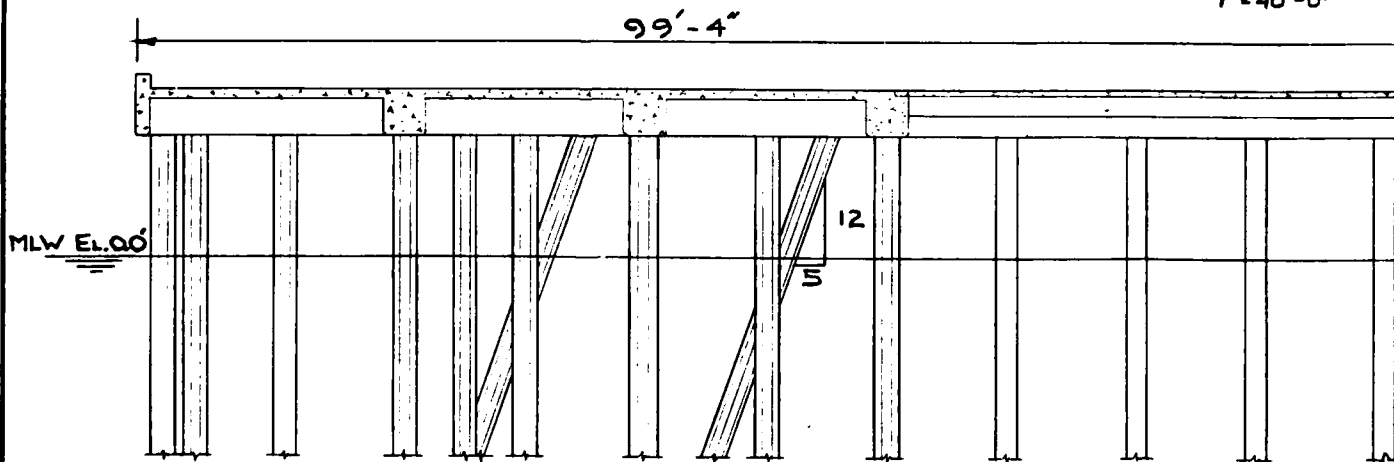
⊗ - CLOSELY INSPECTED BENT. REMAINING BENTS GIVEN CURSORY "SWIM-BY" INSPECTION (SEE SECTION 3.2)

⊠ - SIGNIFICANTLY DAMAGED PILE (SEE SECTION 4.3.2)

1979 ADDITION

PLAN

1" = 40'-0"

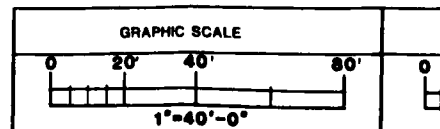


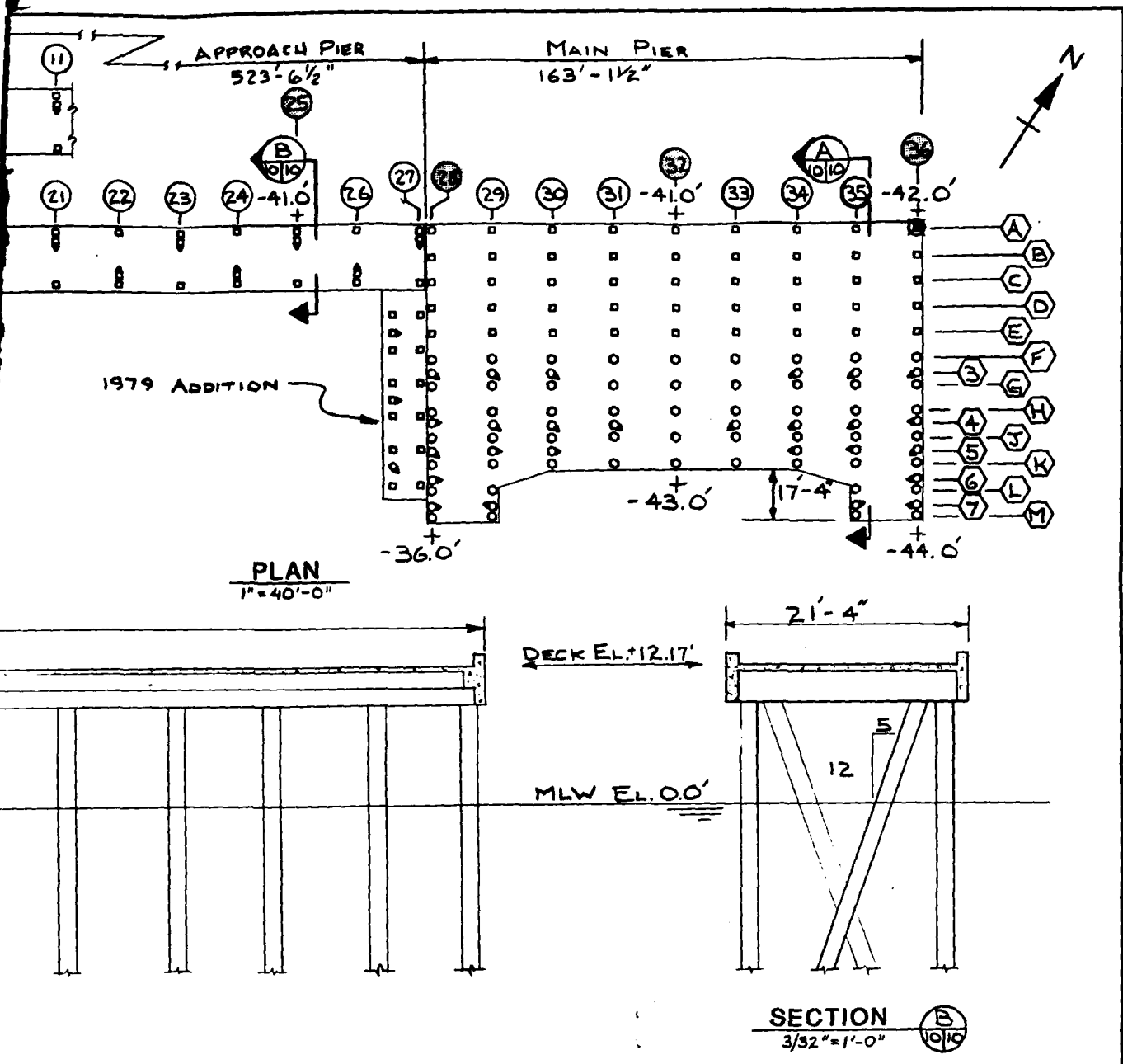
SECTION

3/32" = 1'-0"

A
1019

NOTE: BENT AND PILE DESIGNATIONS ARE ACCORDING TO CHESDIV STANDARDS.





4.3.2 Observed Inspection Condition

Generally, the concrete of the piles was hard and durable, and the corners of the piles were sharp and clear. In Bent 36 of the main pier, Pile A exhibited horizontal cracks up to 3/8" wide between elevations 0.0' and +3.0' above mean low water (MLW). These cracks were present on three of the four faces of the 18" square prestressed, precast concrete pile. Spalling of the concrete from 1" - 2" deep was also associated with these cracks (see Photo #8). This was the only structural degradation noted at Pier CHARLIE.

Soundings taken along the perimeter of the pier ranged from -42.0' below MLW on the north outshore side and -44.0' below MLW on the south outshore side to +8.0' above MLW at the inshore end (Bent 1 is not visible).

Photo #8: Horizontal Crack (Max. 3/8" Wide) Around
Elevation +3.0' (MLW) on Pile A, Bent 36
of Pier CHARLIE



4.3.3 Structural Condition Assessment

Pier CHARLIE is in excellent condition, except for Pile A in Bent 36 of the main pier. The cracks between MLW and elevation +3.0', assumed to have been caused by impact damage, have reduced the structural integrity of the pile. It is not known if the prestressed reinforcing strands have been affected.

4.3.4 Recommendations

The damaged pile in the main pier (Pile A, Bent 36) should be repaired or replaced as soon as possible. In the meantime, pier loading in this area should be restricted to dead load only.

Before any repairs are attempted, a more detailed investigation is recommended to determine whether salt water has infiltrated into the prestressing strands. If this investigation indicates that the prestressing strands are unaffected, this pile can be repaired by patching the void in the concrete pile with welded wire fabric and new concrete. The cost for this repair will vary with the volume of concrete removed, but can be expected to range from \$100 - \$150/linear foot, if divers are not required. If the prestressing strands have been corroded, steel dowels will have to be drilled and grouted to the portions of the pile above and below the damaged area and spliced together at the damaged section. The void should then be filled with welded wire fabric and new concrete. The cost for this repair will be around \$3,500 if divers are not used.

TABLE OF CONTENTS FOR APPENDIX

<u>TITLE</u>	<u>PAGE</u>
Footnotes.....	A-1
Repair Cost Estimates.....	A-2
Structural Analysis Calculations.....	A-4
Thickness Measurements.....	A-6

FOOTNOTES

1. CHARLESTON NAVAL COMPLEX MASTER PLAN; Southern Division,
Naval Facilities Engineering Command, p. III-25.
2. Ibid., pp. III-25 and III-26.
3. Ibid., p. III-26.
4. Ibid., p. II-16.
5. Ibid., p. IV-25.
6. Ibid., p. IV-25.

REPAIR COST ESTIMATE

WHARF ALPHA

- 1) Patch spalled area in three precast, prestressed concrete piles:

Material Cost: \$50 (total volume required = .26 liters)

Diver clean hole, chipping to sound concrete and filling
with epoxy grout -

Labor: \$900/day

Total Cost: Labor and Materials = \$950

REPAIR COST ESTIMATE

PIER CHARLIE

- 1) Patch void in concrete pile after investigation is complete:

Installed Cost: \$100 - \$150/linear foot

- 2) Clean and chip to sound concrete; drill and grout steel dowels into both ends of concrete pile; splice dowels at damaged section; and fill void with welded wire fabric and new concrete.

Mob-Demob: \$2,000

Materials & Labor: \$1,500
(based on 5LF of
replacement) \$3,500

CHILDS ENGINEERING CORPORATION
Box 333
MEDFIELD, MA 02052

JOB 438-80 - USN, Charleston, SC
SHEET NO. 1 OF 2
CALCULATED BY KMC DATE 30 Apr 1982
CHECKED BY DLP DATE 5/12/82
SCALE

Naval Weapons Station - Column Analysis *

Dier Bravo

Steel H-piles HP12x53
 $E = 29.6 \times 10^6 \text{ psi}$ $F_y = 33 \times 10^3 \text{ psi}$
Original Web $t = 0.436"$
Original Cross-Sectional Area, $A = 15.58 \text{ in}^2$

Use average thickness, first discounting high & low readings:

~~.219~~

.312

.310

~~.455~~

.375

Avg = .332"

$L = 49' = 588" = \text{length of column}$

$r = 2.86" \text{ min (original)}$

$k' = 0.5$

$k'L/r = 103$

A varies as thickness

I varies as $A \sqrt{I}$

r varies as $\sqrt{I/A}$

$$C_c = \sqrt{\frac{2E}{F_y}}$$

$C_c = 133.1$, A-7 steel

$$r' = \sqrt{\frac{.332}{.436}} (2.86) = 2.59$$

$L = 49' = 588"$

$r' = 2.59" = \text{average remaining r}$

$k' = 0.5$

$\frac{k'L}{r'} < 133.1 \Rightarrow \text{inelastic buckling}$

range \therefore Use E_t , tangent modulus to calculate $\sigma_{cr} + P_{cr}$.

$k'L/r' = 114$

$$\frac{\pi^2}{(k'L/r')^2} = .00076$$

from σ_{cr} vs. E_t Curve (see Report):

$\sigma_{cr} = 31.7 \text{ ksi}$

$$P_{cr} = 31.7 \left(\frac{.332}{.436} \right) (15.58) = 376 \text{ K}$$

where $\sigma_{cr} = \frac{\pi^2 E_t}{(k'L/r')^2}$

and $P_{cr} = \sigma_{cr} (A_r)$

$$P = \frac{376}{2.75} \left(\frac{1}{2} \right) = 68 \text{ tons}$$

[$A_r = \text{average remaining cross-sectional area}$]

[$P = P_{cr} / \text{Factor of Safety}$]

* Refer to Childs Engineering Report entitled "Analysis of Remaining Strength of Concrete Jacketed Steel H-Piles", Feb. 1982, for explanation of terms and method.

CHILDS ENGINEERING CORPORATION
Box 333
MEDFIELD, MA 02052

JOB 438-80 - USN - Charleston, SC
SHEET NO 2 OF 2
CALCULATED BY KMC DATE 30 April 82
CHECKED BY DLP DATE 5/4/82
SCALE

PIER BRAVO - cont'd.

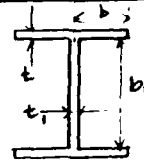
Check local buckling:

$$\frac{b}{t} = \frac{6''}{.219''} = 27.4 > 16.5$$

Flanges

$$\frac{b'}{t'} = \frac{10.9''}{.219''} = 49.8 > 44$$

Web



∴ Both ratios exceed allowable values.

$$F_c : \sigma_{cr} = \frac{.416(29.6 \times 10^6)}{1 - (.27)^2} \left(\frac{1}{27.4} \right)^2 = 17,691 \text{ psi}$$

$$\text{Web: } \sigma_{cr} = \frac{3.29(29.6 \times 10^6)}{1 - (.27)^2} \left(\frac{1}{49.8} \right)^2 = 42,355 \text{ psi} \Rightarrow \text{Not controlling}$$

$$\text{Local Buckling } P = (17,691 \text{ K}) (.2A) [(12')^2 + 10.9'] \\ = 135 \text{ K} = 67.5 \text{ tons}$$

Overall Buckling $P = 68 \text{ tons}$ ∴ Local Buckling may be controlling (very close).

Note: Concrete jackets are in poor condition and considered not effective in shortening effective column length or carrying column load.

CONCLUSION: Piles are designed for a maximum bearing of 50 tons.
∴ From the present analysis, the piles are adequate to handle the imposed loads.

THICKNESS MEASUREMENTS

PIER BRAVO

<u>Bent</u>	<u>Pile</u>	<u>Elevation (MLW)</u>	<u>Flange Thickness</u>
62	#2	-1.1'	7/32" ²
60	C	-40.1'	5/16" ²
55	E	-4.1'	.310 ¹
53	F	-4.0'	.455 ¹
30	F	-20.6'	3/8" ²

1. Ultrasonic Measurement
2. Caliper Reading

END

DATE
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